



## Development of a dso-market on flexibility services

Ding, Yi; Hansen, Lars Henrik; Cajar, Peder Dybdal; Brath, Poul; Bindner, Henrik W.; Zhang, Chunyu; Nordentoft, Niels Christian

*Publication date:*  
2013

*Document Version*  
Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*  
Ding, Y., Hansen, L. H., Cajar, P. D., Brath, P., Bindner, H. W., Zhang, C., & Nordentoft, N. C. (2013).  
*Development of a dso-market on flexibility services.*

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.



STRATEGIC PLATFORM FOR INNOVATION AND  
RESEARCH IN INTELLIGENT POWER [IPOWER]

# DEVELOPMENT OF A DSO-MARKET ON FLEXIBILITY SERVICES

<i>Category</i>	<b>Report</b>
<i>Identifier (task etc)</i>	<b>N/A</b>
<i>Status</i>	<b>Released for External Use</b>
<i>Version</i>	<b>Version 5</b>
<i>Access</i>	<b>WorkPackage 3.8</b>
<i>Editors (name and affiliation)</i>	<b>Niels Christian Nordentoft</b>
<i>Date</i>	<b>23-04-2013</b>

**Funding:** Joint by partners and Danish Government (iPower platform has been granted support from SPIR - Strategic Platform for Innovation and Research).

## DOCUMENT CONTROL

### List of Contributors

Yi Ding	Working Group leader
Lars Henrik Hansen	
Peder Dybdal Cajar	
Poul Brath	
Henrik W. Bindner	
Chunyu Zhang	
Niels Chr. Nordentoft	

### List of Reviewers

	Date
WP leaders	
Steering Group	

### Latest Version of this Document

### Related Documentation

n/a

### Summary of Changes



## 1 CONTENTS

Document Control .....	2
2 Introduction .....	6
3 Motivations of each market player .....	8
4 The DSO's demand – the needs of the DSO .....	13
4.1 Case 1 - Regular growth in electricity consumption .....	13
4.2 Case 2 - Active use of reservecapacity in the grid .....	15
4.3 Case 3 - High power flow caused by activation of regulating power for the TSO .....	17
4.4 Case 4 - High power flow caused by very low prices of electricity .....	18
4.5 Case 5 – Voltage level issues caused by local generation .....	18
4.6 Case 6 – Reactive power issues caused by local generation .....	19
5 The Products – the flexibility services .....	23
5.1 Introduction to price setting of products .....	23
5.1.1 Equilibrium of supply and demand cost .....	23
5.1.2 Contractual possibilities .....	25
5.1.3 Possible timeline in contracting flexibility products .....	26
5.2 Introduction of product specifications .....	27
5.3 Products for Load management .....	28
5.3.1 Product specification no 1: PowerCut Planned .....	28
5.3.2 Product specification no 2: "PowerCut Urgent" .....	32
5.3.3 Product specification no 3: "Power Reserve" .....	36
5.3.4 Product specification no 4: "PowerCap" .....	40
5.3.5 Product specification no 5: "PowerMax" .....	45

---

5.3.6	Comparison of DSO-products for load management .....	48
5.4	Products for Voltage management.....	49
5.4.1	Product specification no 6: "VoltageSupport" .....	49
5.4.2	Product specification no 7: "VArSupport" .....	54
5.5	Product specifications – Summary .....	58
5.5.1	Flexibility Products for Load management - Summary .....	58
5.5.2	Flexibility products for Voltage management - Summary .....	60
6	Basic Market design .....	63
6.1	Market design .....	63
6.2	The need for a flexibility Clearing House – FLECH .....	64
6.2.1	Coordination in serving flexibility to both DSO and TSO .....	66
6.2.2	Risk of malicious behaviour from the Aggregator .....	68
6.3	Possible trading setups .....	69
7	Market Issues / Problems.....	70
7.1	Imbalance when serving flexibility – Placement of imbalance costs.....	70
7.2	Aggregator and Retailer conflict - Customer rights? .....	72
7.3	Bankruptcy of Aggregators .....	72
7.4	incentives for DSO to invest in flexibility services .....	73
7.5	Adjustments in TSO ancillary service markets.....	74
8	Recommendation of iPower demonstrations .....	75
9	Conclusion .....	77
10	References .....	78

## 2 INTRODUCTION

With the increasing demand on generation from renewable energy resources (RES), the power system in Denmark is at present (and has been for some decades) transitioning from a centralised and mainly coal based system to a system with a great variety of energy resources both centralised and decentralised. This has led to roughly 20% wind power in the electricity production (yearly average), and increased use of biomass. Furthermore, during 2011-2012 the installation of photovoltaics (PVs) has truly accelerated from 3 MW to roughly 100 MW installed power (Danish peak demand ~ 6000 MW). This evolution is very much in line with the political goals of CO<sub>2</sub> emission reductions.

The electricity production is, though, affected by the carbon emission allowances putting a cap on CO<sub>2</sub> emissions, which during time automatically should lower the CO<sub>2</sub> emissions from electricity production, speeding up the already started transition. However, other sectors such as transportation have no cap on CO<sub>2</sub> emissions. Therefore, also electric vehicles (EVs) are at present highly subsidized, leading to high expectations for the share of EVs in Denmark. Finally, subsidies have also been given to step up transition from oil-boilers for house heating to use of heat-pumps.

This transition will all in all lead us in the direction of lower CO<sub>2</sub> emissions from Denmark. However, this transition offers new challenges for both the electricity system and for the electrical grids.

For the Transmission system operator (TSO), balancing the frequency will be an increasing challenge, with increased RES, as the task of ensuring sufficient resources for balancing will increase with an increased share of intermittent RES. This is illustrated in Figure 1.



Figure 1: Illustration of the TSO challenge of balancing consumption with variable production.

For the distribution system operators (DSO) new challenges on contingency and compliance with the +/-10% voltage limits will arise from increased consumption for EVs and residential heat pumps (HPs), together with increased local production from PVs. Figure 2 illustrates a case where a congestion situation arises on the 0.4 kV grid due to high consumption. Figure 3 illustrates the potential voltage issues due to the fact that during the year 0.4 kV feeders can experience both significant voltage rise due to high level of local generation and low voltage due to high local load. This situation is already happening today at few local feeders and there are at present no means installed to overcome the situations. Therefore investments will be needed.

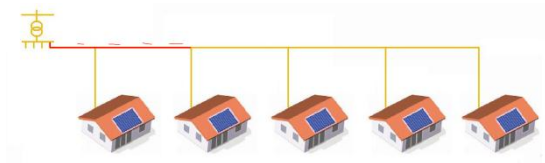


Figure 2: Illustration of possible future overload situations.

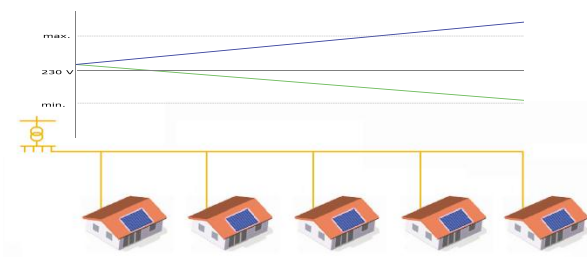


Figure 3: Illustration of possible future voltage issues.

With this expected future scenario, a new concept on demand response (DR) has been suggested in order to help both TSO and DSOs with their coming challenges.

This concept should not be mixed up with other opportunities in gaining value from flexible consumption, such as:

- Special connecting fee schemes
- Dynamic, variable or powerbased tariffing
- etc.

The concept should therefore not be seen in competition to the other possibilities mentioned above, all of the suggestions might work perfectly side-by-side. This concept simply provides several other benefits to society, in mobilizing the present unused resources of flexibility at electricity consumers and producers.



### 3 MOTIVATIONS OF EACH MARKET PLAYER

Each market player should be driven by their own possibility to benefit from supply or demand of flexibility services. From the consumer/DER, as supplier of flexibility, over the Aggregators, as brokers of the consumer/DER flexibility, to the TSO and DSOs, as demanders of flexibility services. This is illustrated by the green stars in Figure 5 below.

The setup in which this can be done is illustrated in Figure 4, below. This setup will be further elaborated on in section 6.

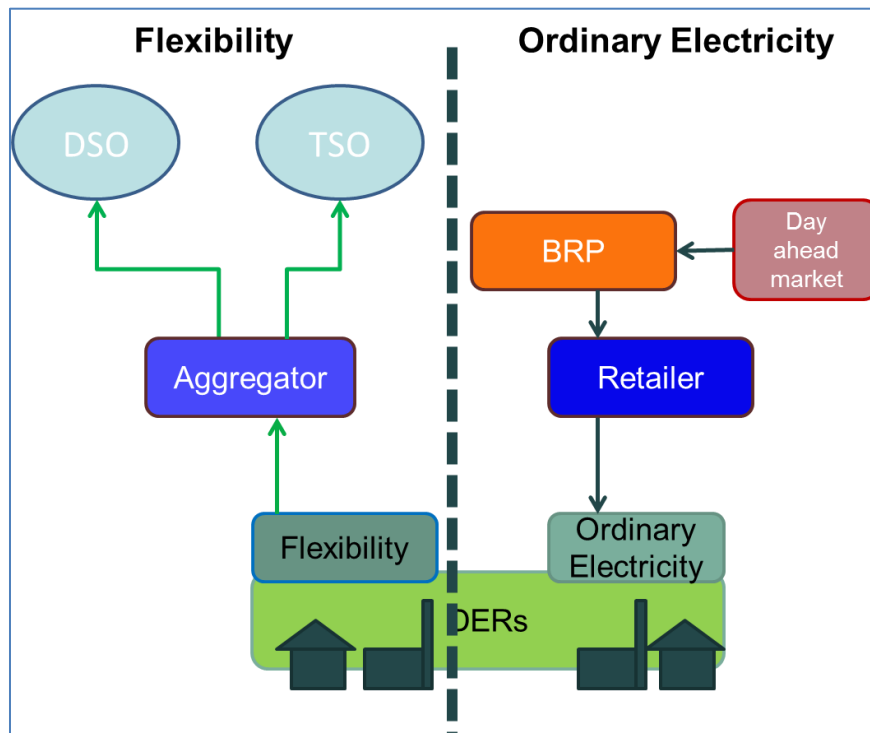


Figure 4: New market player setup for trading flexibility products.

The motivations of the main actors are elaborated below in short.

#### The Consumers

Traditionally the consumer is equal to the end customer in the electrical system we know today. However, very soon the consumers will also be suppliers of flexibility in terms of load shifted or load shed kWh, from their relevant appliances (DERs, e.g. heating system, ventilation, industry processes etc.). The consumers will have other primary doings to tend to than controlling their consumption 24 hours a day. Furthermore, the consumers are in general not expected to have time or

sufficient interest, in achieving the needed knowledge of the electricity markets. Bearing this in mind, the consumers are expected to need some professional broker to sell their flexibility to the highest possible bidder.

In Figure 5 the consumer is illustrated as a household. However, in this context the consumer could be both consumers from both the residential, commercial and industrial sectors. But actually also from decentralised power production plants. All it takes is that the consumer has a sufficient amount of distributed energy resources (DERs) with the possibility to be flexible with a part of the power consumption. A sufficient amount of flexibility are defined by, whether or not there is a business case in activating the flexibility from the DER.

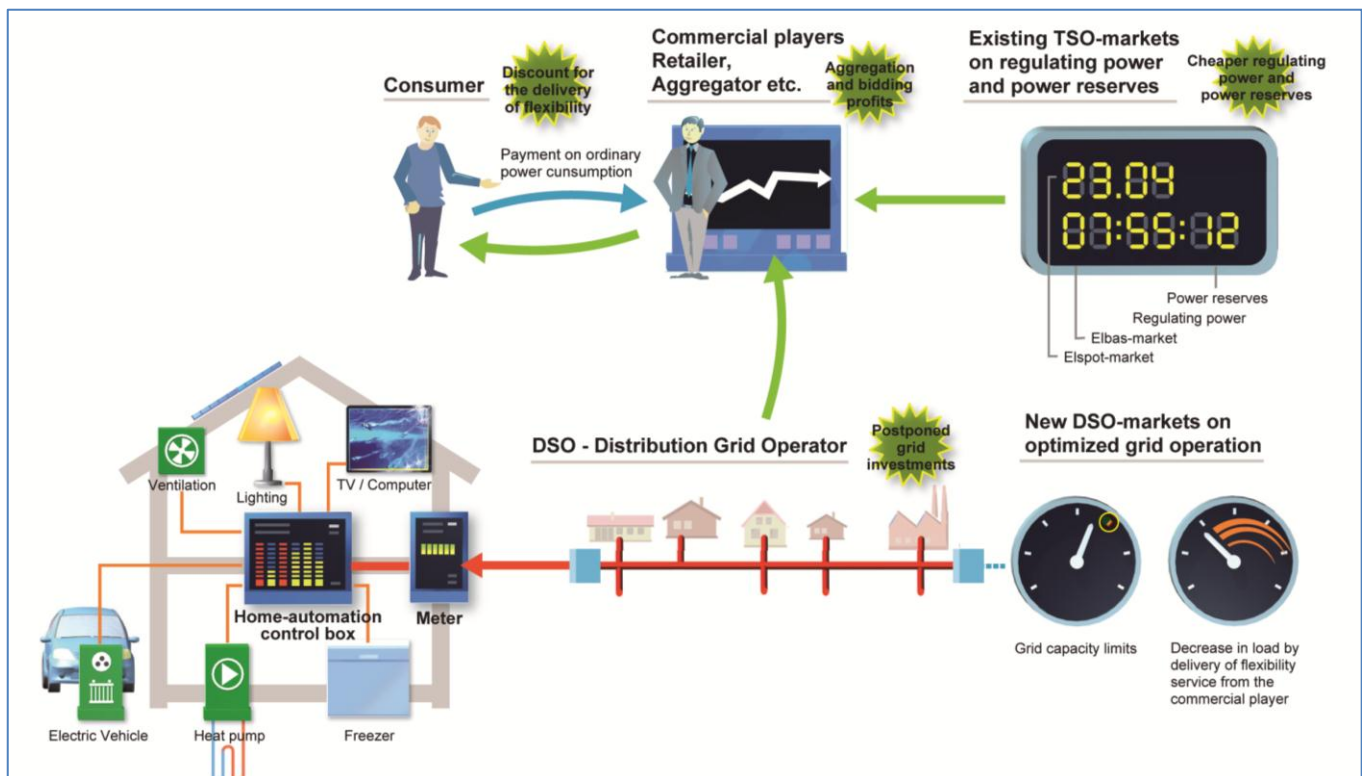


Figure 5: Illustration of the consumer involvement in trading flexibility.

In supplying flexibility the consumers will be paid, by their affiliated Aggregator, equivalent the amount of flexibility delivered, in order to make it interesting to the consumers to participate. The payment setup will be of many various types.

### The Aggregators:

The Aggregator is a new commercial entity, expected to be interested in making business by aggregating flexibility of the consumers, DERs, pack it, and sell the aggregated flexibility to the highest possible bidder, would it be the DSOs or the TSO.

Thereby the Aggregator will be supplier of the aggregated flexibility of his affiliated consumers, DERs. A method for the Aggregators task in packaging and optimizing the use of his affiliated DERs, have been described in [1], using resource polytopes. In short the Aggregator will package the flexibility of his contracted consumers into a common resource polytope as illustrated in Figure 6 (red-dotted areas, sum up to the common blue-dotted area). From his entire flexibility portfolio the Aggregator will be able to package the resource polytopes (with the lowest marginal costs) that correspond exactly to the demanded flexibility products of the TSO, DSOs and BRPs.

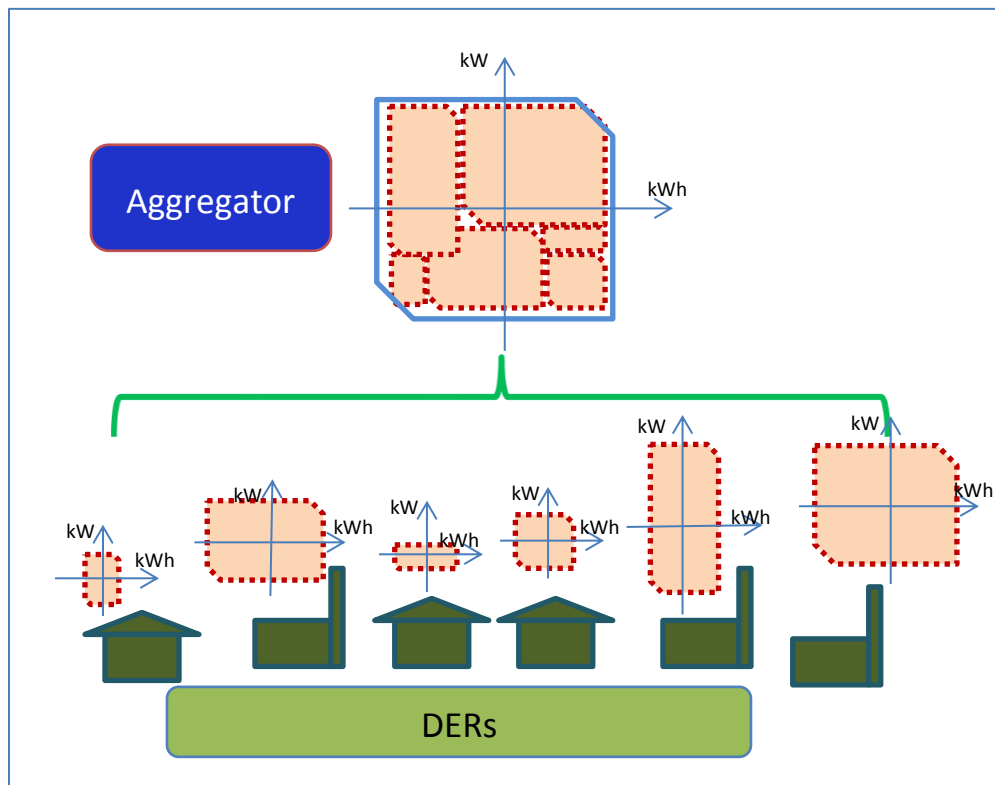


Figure 6: Illustration of resource polytopes, where resources from DERs are stacked and packaged into products demanded by TSO, DSOs and BRPs

The Aggregator will further have to have thorough knowledge of the electricity markets and through this be able to put the right price on the flexibility products that they deliver in cooperation with the affiliated consumers.

The Aggregator will be paid by the DSOs and the TSO for delivering flexibility services. From this payment the Aggregators will pay their affiliated consumers, according to their contractual agreement. As the Aggregator can deliver services to both the DSOs, the TSO and possibly the BRPs, the Aggregators can distinguish themselves through multi-price optimization, where the Aggregator seeks to get the highest price (at lowest risk) for the flexibility served.

### **The Balance Responsible Parties (BRPs)**

The Balance Responsible Party is an existing commercial entity. The primary role of a consumption BRP is to buy power / Energy (kWh) in the Wholesale market, in a quantum that to the highest extent possible corresponds to the actual amount of Energy consumed by the customers. Hence the name *balance responsible party*. Only BRPs are at present allowed to trade at the wholesale markets (not to be mixed up with the financial markets).

The BRP buys electric energy on behalf of 1 or more Retailers, or in other words the BRPs are wholesale supplier of the Retailers, similarly as for grossery stores etc.

The motivation for the BRPs in trading flexibility is twofolded. On the one hand some BRPs are already today trading flexibility from smaller CHP plants, etc. in the regulating power market. Therefore expanding their business by including even smaller units, and also demand side units, might be straight forward. On the other hand the BRPs are not expected to push for the task of aggregation at present, therefore independent Aggregators who can move fast, on mobilization, becomes important.

### **The Retailers**

The Retailer is also an existing commercial entity working within the ordinary power market, buying electrical energy from their associated BRP and from this serving the consumers with energy. The Retailers therefore work on the retail side of the ordinary power market. As of today the Retailers have no direct motivation within trading flexibility.

However trading flexibility is a related business. From this it is likely that the Retailers will look into whether they should expand, by also having an affiliate sister company or internal competence in being an aggregator.

### **The DSOs:**

The DSO is a monopoly, who in this context will be demander, putting a demand on flexibility services, that makes the DSO able to handle increased loads on distribution grid feeders. This will be interesting to the DSO if the alternative of buying flexibility services in hours of high load is cheaper than upgrading highly loaded distributions grid feeders. The critical amount of hours of overload, where the costs of grid upgrade will turn out being cheaper than buying load reduction, will vary from feeder to feeder. The possibility of choosing a cheaper alternative than grid reinforcement will be the prime motivation of the DSOs. The economy in choosing from the two alternatives are illustrated in Figure 7 below.

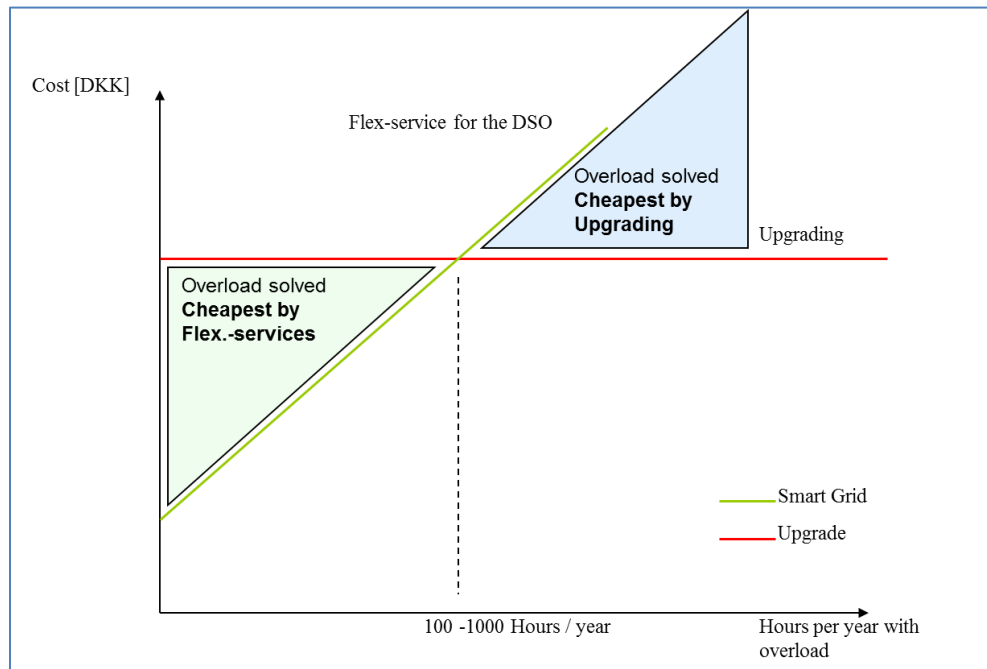


Figure 7: Illustration of the economic motivation for the DSOs in using flexibility products.

### The TSOs:

The TSO is a monopoly. At present the TSO is running several markets on ancillary reserves. These markets are used to ensure the balance of frequency and power, which the TSO has the responsibility of maintaining. These markets are presently supplied by central and decentralized power plants, typically coal, oil or gas fired. As it is expected that these resources will be increasingly scarce, due to the decrease in operation hours caused by the prioritization of RES, reserves from these resources will decrease in quantity and from this possibly grow in price.

The motivation of the TSO is that by the mobilization of new flexible loads the supply on the markets on manual and automatic reserves, will grow, and thereby hopefully lead to a decrease in the TSO's cost on these reserves.

## 4 THE DSO'S DEMAND – THE NEEDS OF THE DSO

As markets targeting TSO-needs, to a large extent already exists today, this report focuses on establishing a market targeting DSO needs, in order to make the most possible value from the flexibility resources distributed across the distribution grid.

However the needs of the DSO are not similar to the TSO. In this section the characteristics of the DSO challenges and thereby their demand for services, will be described. The description is made for several various cases as the different cases will challenge the DSO in different ways. By this the characteristics of the DSO demands will also vary from case to case.

As all cases are likely to occur this means that several different flexibility services will have potential interest to the DSO. In the subsections below these different cases will be described.

### 4.1 CASE 1 - REGULAR GROWTH IN ELECTRICITY CONSUMPTION

Case 1 describes the situation with a growth in the regular electricity consumption. The growth is in this case interpreted to come from either an increase in consumption from traditional appliances or from new appliances such as EV's (Electrical Vehicles) and HP's (Heat Pumps). Different scenarios for growth in consumption from EV's and HP's, indicates that the yearly maximum consumption will increase beyond the present capacity-limit of some 10 kV feeders.

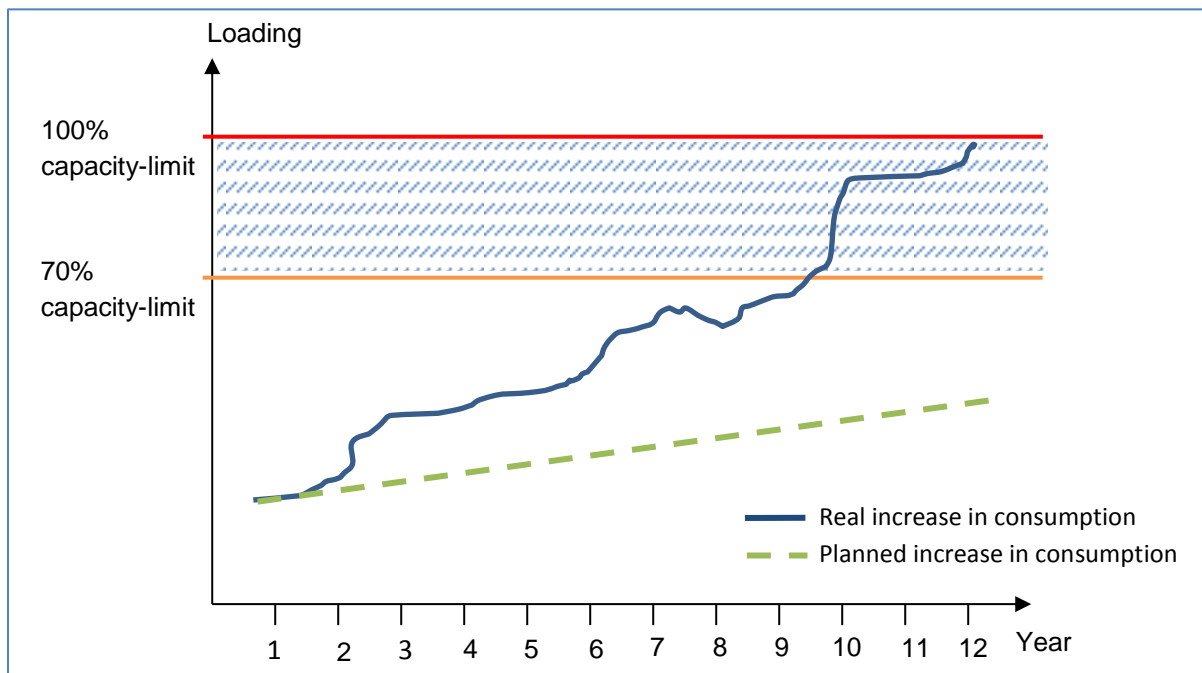


Figure 8. Discrepancy between estimated and actual increase in consumption.

Dependent of the characteristics of each 10 kV feeder at some point in time the hour with maximum power consumption will reach the 70% capacity limit, see Figure 8, where the shaded 30% capacity band exemplifies the reserved safety capacity

equivalent to the N-1 rule [2]. Thus the 70% capacity limit is used as a rule-of-thumb, in normal operation, in distribution grid planning. It is actually not a general limit and is sometimes lower and sometimes higher, but in this context it is reasonable to use as a rule-of-thumb (see report from iPower WP3.1.). It should be noted, that on a typical 0.4 kV feeder the capacity limit is equivalent to the capacity of cable – i.e. 100%.

At present the 70% capacity limit is used in determining whether or not a 10 kV feeder should be upgraded. However as the load on each 10 kV feeder will grow at a moderate pace, only a few hours will exceed the 70% capacity limit the first year of overload. The number of hours with load exceeding the capacity limit will assumedly increase the following years. Illustrating the load in each of the 8760 hours of a year as a duration curve, as done in Figure 9, one can see that there are many hours with medium or low load, to differ the load from the peak hours to.

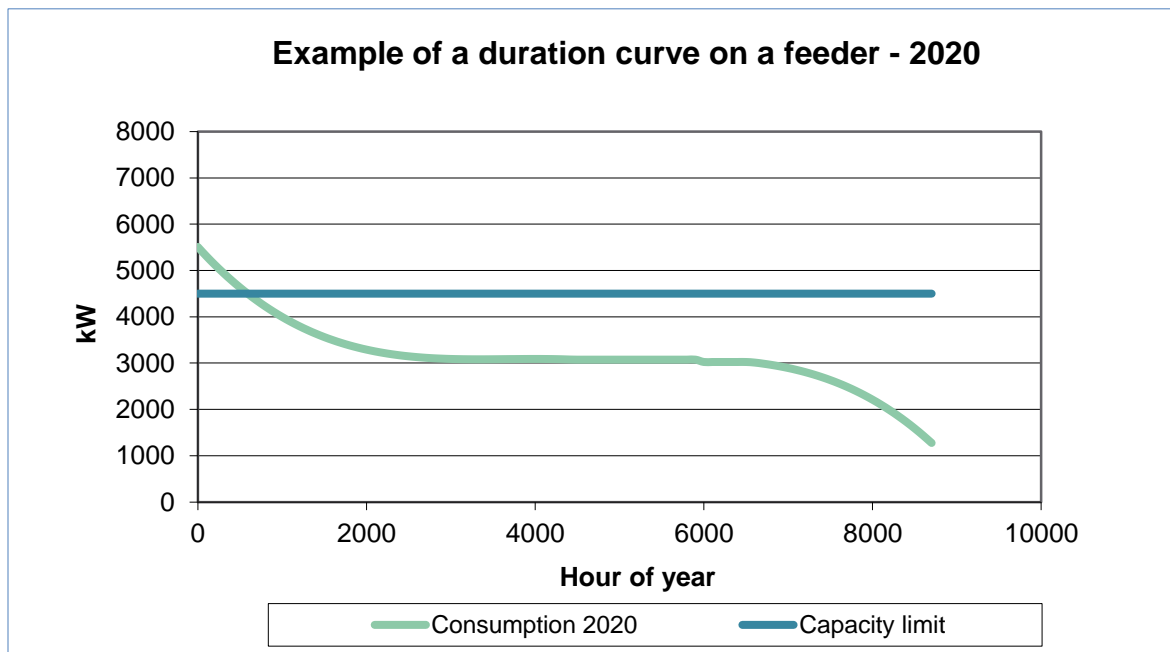


Figure 9. The distribution of the load in each hour of a year illustrated by a duration curve.

Furthermore from Figure 10 it can be seen that the hours of peak load often only occur a couple of hours a day in the days of the year with the highest load (typically in the winter time in Denmark).

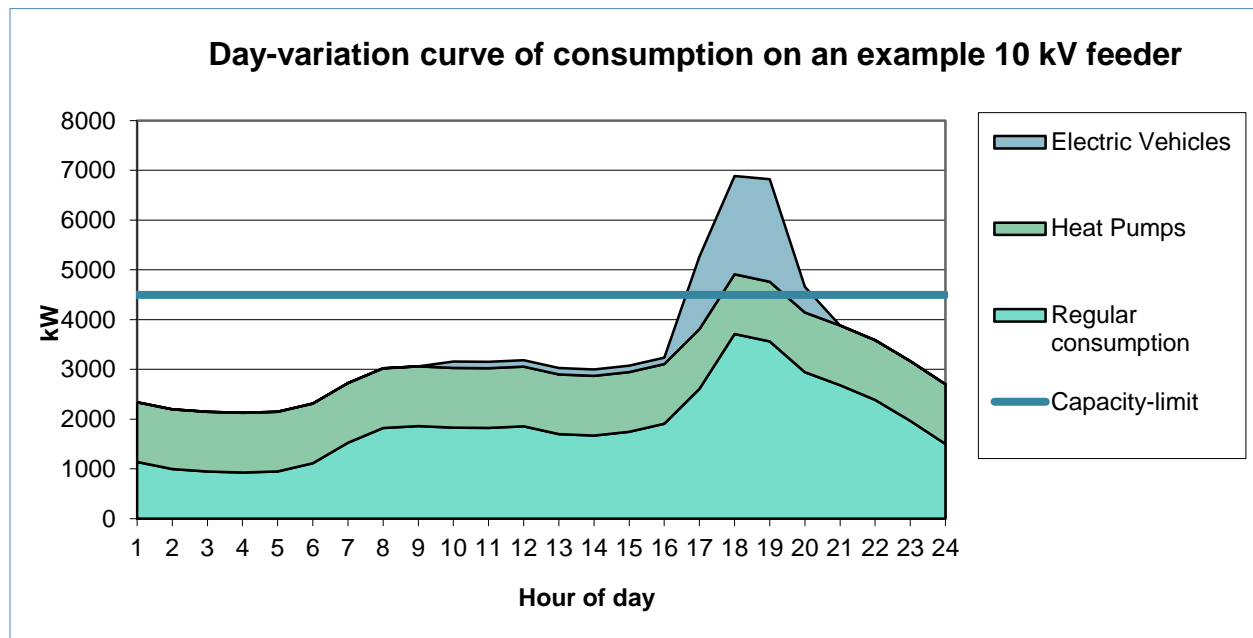


Figure 10. 10 kV feeder example of the hourly load during a day split in EV, HP and regular consumption.

Case 1 is therefore describing a situation where the DSO will be likely to put a demand on flexibility services on differing the increased load from the hours with peak load. As long as the alternative of buying such flexibility services are cheaper to the DSO than buying grid upgrades flexibility services will be interesting.

## 4.2 CASE 2 - ACTIVE USE OF RESERVECAPACITY IN THE GRID

As described in section 4.1 at present the 70% capacity limit is as a “rule-of-thumb” used in determining whether or not a 10 kV feeder should be upgraded.

The reason for having the 70% limit is the fact that the DSOs at present needs to save the remaining 30% capacity in the 10 kV feeders in order to be able to help supply neighboring feeders in case they get faulted (the N-1 rule). In case of a faulted 10 kV feeder a reserve-supply situation will be established, as illustrated in Figure 11. In these cases it is accepted by the DSOs to increase the load of the neighboring 10 kV feeders up to 100%, now serving also the consumers at the faulted 10 kV feeder.

However this leaves significant spare capacities in the 10 kV feeders which are only used on rare occasions. The DSOs could benefit from using the reserve capacity between the 70% capacity limit and the 100% capacity limit, if the DSO could obtain sufficient security that they could lower the load of the 10 kV feeders, by using flexibility services, and thereby securing that they can deliver reserve supply, in case of a faulted 10 kV feeder.



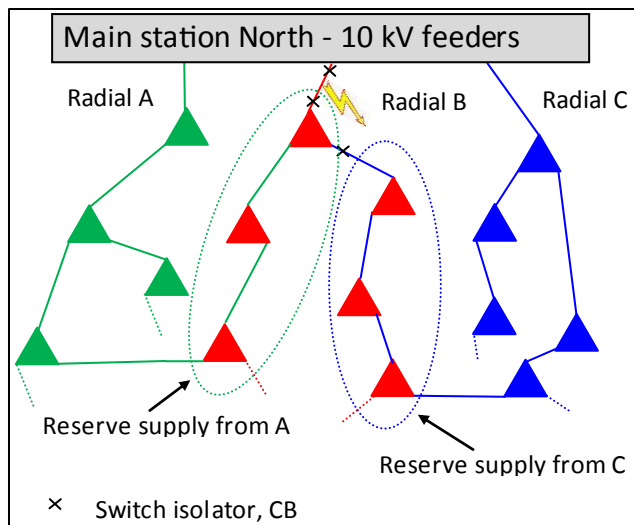


Figure 11. Example of a cable error close to the main station on feeder B. The sub grid of feeder B is split in two sub grids, which are supplied from neighbor sub grids A and C.

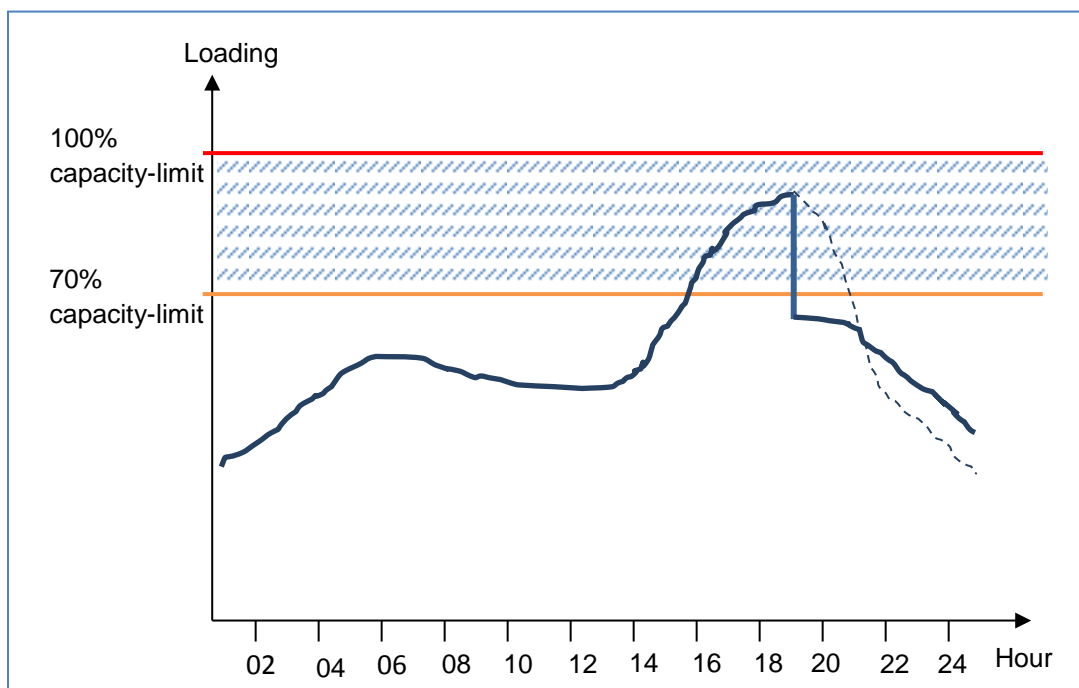


Figure 12. Example of load reduction in case of emergency operation.

The interesting flexibility services for the DSO in case 2 are if the DSOs by buying the flexibility service can be 100% sure that there in the case of emergency operation, exists interruptible customers within the bought flexibility service, delivering the needed load reduction. In Figure 12 the needed type of flexibility service is illustrated.

One should note that this flexibility service – if 100% reliable – will open up on the DSOs possibilities of utilizing the reserved capacity between the 70% capacity limit and the 100% capacity limit.

#### 4.3 CASE 3 - HIGH POWER FLOW CAUSED BY ACTIVATION OF REGULATING POWER FOR THE TSO

The initial state of this case is that the loading on a certain 10 kV feeder are normal and somewhat below the 70% capacity limit. However during the day (and on several occasions before) the TSO have activated Regulating Power services from resources located on this particular 10kV feeder, in order to help adjust the balance in the power system. There should of cause not be any initial limitation on the resource locate on the particular 10kV feeder in delivering regulating power to the TSO. If value is made from activating the resources on the particular 10kV feeder it should be done. However it poses a challenge to the DSO, in handling sudden, unexpected overloads.

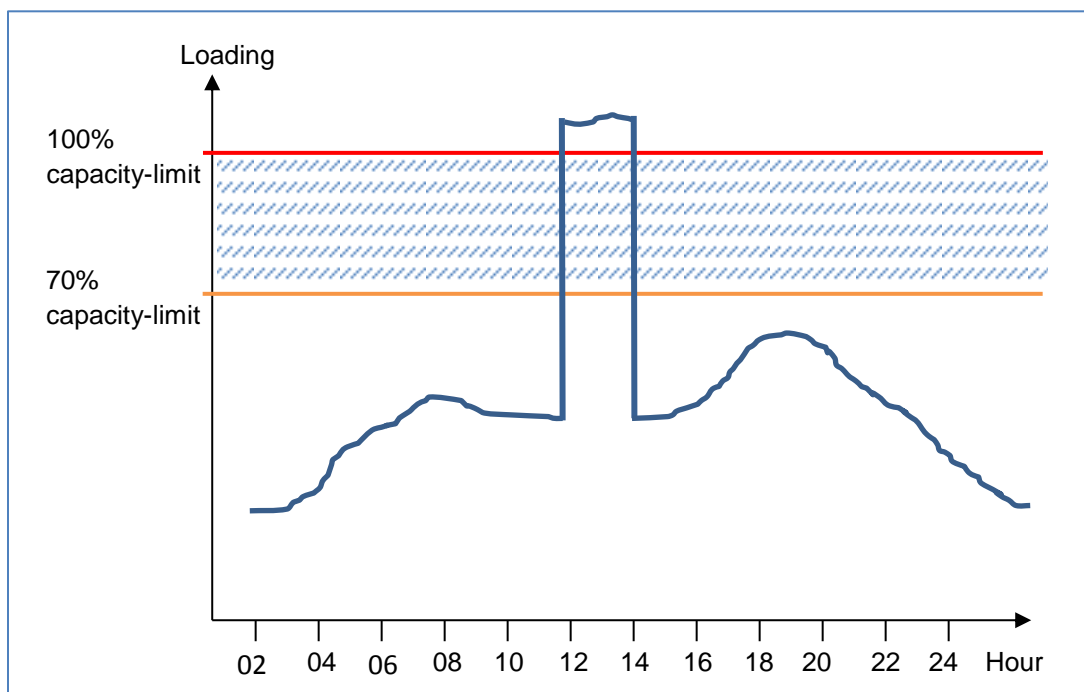


Figure 13. High power flow scenario e.g. caused by activation of regulating power provision for the TSO.

The interesting flexibility services for the DSO in case 3 would be to ensure some sort of coordination between the activation of resources at the 10kV grid to deliver regulating power to the TSO and the present loading of the 10 kV feeders.

#### 4.4 CASE 4 - HIGH POWER FLOW CAUSED BY VERY LOW PRICES OF ELECTRICITY

The initial state of this case is that the loading on a certain 10 kV feeder are normal and somewhat below the 70% capacity limit. However during the day the Elspot price e.g. between 5 and 6 PM are to be negative. This will be known on before-hand (Elspot prices are settled for every 24 hours a day, at 12 o'clock the day before). Many of the consumers/DERs are expected to be hourly billed in the future thereby have a large incentive to seek the low hourly prices. The consequence of the low Elspot price example above could be that consumers will place more consumption in the low price hours. The result from this will be that the consumption on the 10 kV feeder will exceed the capacity limit of the feeder. The case will most likely be valid for several feeders in the future if nothing is done.

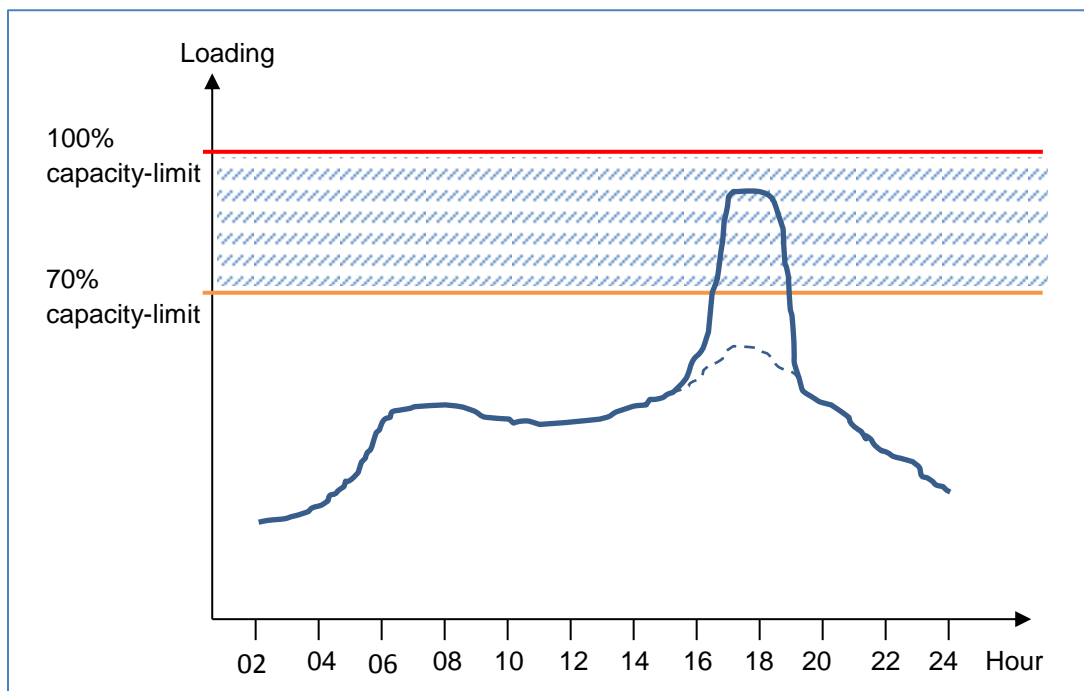


Figure 14: Consequence of forecasted low price hour in the day ahead market (Elspot) creating a peak load.

The interesting flexibility services for the DSO in case 4 would be to ensure that grid capacity somehow is taken into consideration.

#### 4.5 CASE 5 – VOLTAGE LEVEL ISSUES CAUSED BY LOCAL GENERATION

An increasing penetration of DG (distributed generation) will eventually challenge the absolute voltage limits for the different voltage levels as well as the voltage distribution on the 0.4 kV feeders as sketched in Figure 15.

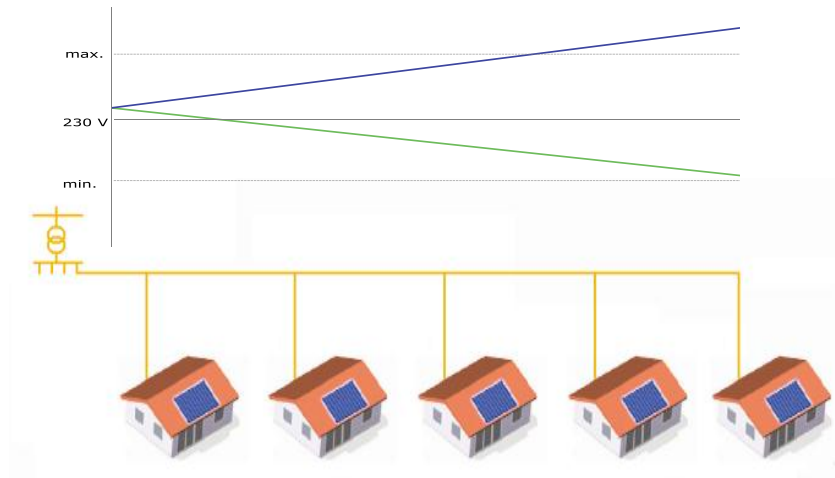


Figure 15: Local power generation will influence the voltage level down the feeder.

In Denmark the secondary substations (10/0.4 kV) do neither facilitate remote control of the tap changers nor frequent tap changing in general. In grid areas with high DG penetration, the DSO would either have to install:

1. new substation with remote controlled tap changers, or
2. establish sources for voltage support across the grid.

As the DSO are committed into serving each customer (at the point of common coupling), with electrical power, within the voltage-limits of  $\pm 10\%$  of  $U_{nom}$ , the DSO will be interested in any solutions that will help them in fulfilling their responsibility, as long as it is sufficiently cheap, easy to carry-out and reliable.

#### 4.6 CASE 6 – REACTIVE POWER ISSUES CAUSED BY LOCAL GENERATION

As described in Case 5, local generation will affect the voltage levels. On a longer time scale also the reactive power balance in the distribution grid could be influenced. Denmark is split into fifteen regions regarding reactive power control – as illustrated in Figure 16 – each region must stay with a predefined reactive power band.

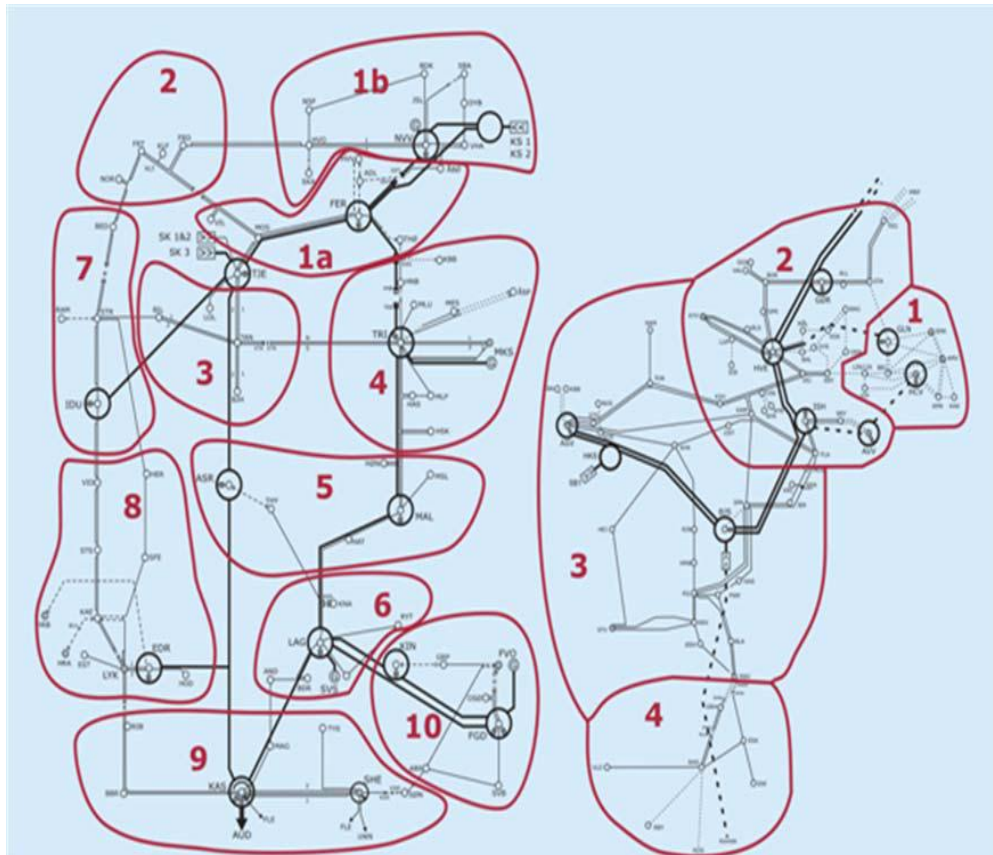


Figure 16: Concerning reactive power control Denmark is split into fifteen regions. Source: [3].

The variations in the daily consumption will also imply variations in the reactive power flow internally in each of the reactive power control regions. The present substantial increase in penetration of PV in the distribution grid will accentuate these variations. Therefore the DSO could potentially be forced to establish means of reactive power compensation equipment in order to fulfill the reactive power band. In Figure 17 below the absolute values of the MVar bands in each region is shown.

	Region 1a	Region 1b	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8	Region 9	Region 10	Sum
Danmark vest	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar	Mvar
Mvar aftag												
max 1% fraktil	45	48	17	51	87	43	57	46	115	61	79	652
max 10% fraktil	21	23	8	24	41	20	27	22	54	29	37	305
max 25% fraktil	13	14	5	14	24	12	16	13	33	17	22	183
Mvar overskud												
min 75% fraktil	-6	-6	-2	-7	-12	-6	-8	-5	-14	-7	-11	-82
min 90% fraktil	-12	-12	-3	-13	-23	-12	-16	-10	-28	-15	-21	-164
min 99% fraktil	-23	-23	-7	-26	-46	-23	-33	-20	-56	-30	-43	-329

	Region 1	Region 2	Region 3	Region 4	Sum
Danmark øst	Mvar	Mvar	Mvar	Mvar	Mvar
Mvar aftag	200	100	100	100	500
Mvar overskud	-23	-46	-38	-13	-120

Figure 17: Definition of MVar bands. Source: Energinet.DK: Teknisk Forskrift : TF 2.1.3 Dansk MVar-ordning (2010).

To provide further elaboration on this in Figure 18 an example from region 4 is shown.

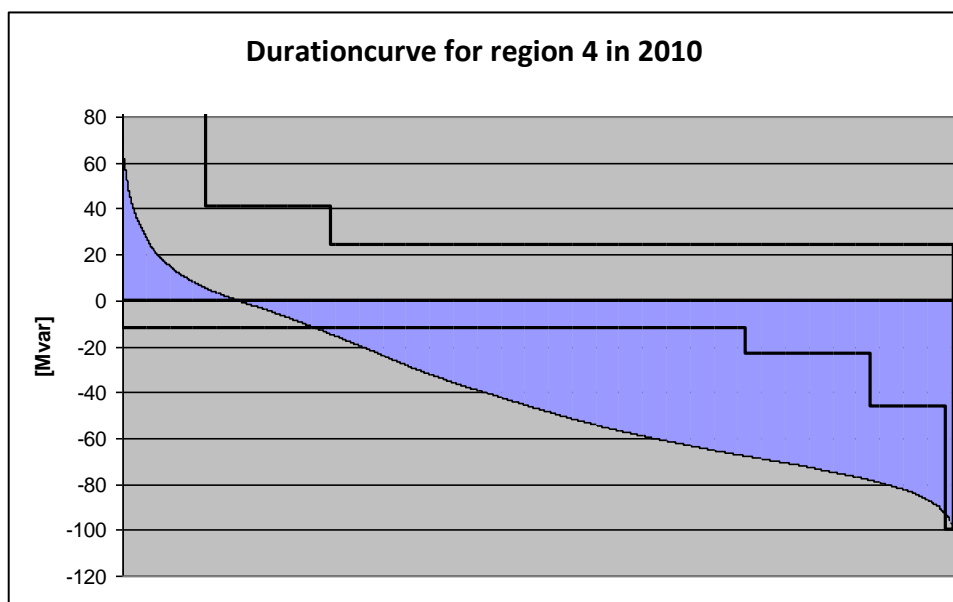


Figure 18: Example of reactive power flow duration curve for Region 4 in 2010.

The interesting flexibility services for the DSO in case 6 would be to get some sort of low cost alternative to conventional reactive power compensation equipment, at present shunt reactors, shunt capacitors and possibly in the future (static synchronous compensator (STATCOM) or Static Var Compensator (SVC)). The most likely alternatives would be MVar support from decentralized generation, e.g. medium sizes power plants (1-50 MVA), who regulates the magnetization of their synchronous generators, but also advanced DFIG wind turbines will be able provide MVar support, even in low winds.

## 5 THE PRODUCTS – THE FLEXIBILITY SERVICES

At present the DSOs have posted as good as no specifications of interesting flexibility products. The reason is possibly that many DSOs have either not focused on this area yet, or are uncertain whether buying flexibility should be a strategic option to them. This poses a barrier for helping them as knowledge on DSOs possible demands of cause are central, in unlocking the value chain.

In this section different flexibility products will be presented, as will examples on possible contractual setups and thoughts on pricing of flexibility products.

### 5.1 INTRODUCTION TO PRICE SETTING OF PRODUCTS

In order to put the coming examples on pricing and contractual setup in the right context, this section will shortly introduce the size of value of flexibility products for the DSOs. This size will present the scale on price in which DSOs will be interested in flexibility products. In this way expectations to the value of flexibility products for the DSO will be set in the right context.

#### 5.1.1 EQUILIBRIUM OF SUPPLY AND DEMAND COST

Naturally the maximum price on flexibility products for the DSOs will be set by the DSO. The reason for this are that the maximum price on flexibility products will be set from the DSOs alternative costs in reinforcement. This will so to say form the price-cap, on flexibility products for the DSO.

Hence the final price will depend on what price the Aggregator offer his flexibility products at. If it is sufficiently low the DSO are likely to use the offered flexibility product. This is illustrated in Figure 7 above.

If the only alternative to the DSO, of buying this flexibility product is to upgrade its grid components (cables, transformers, etc.), the price setting could be done on the basis of the 1<sup>st</sup> year value of these upgrades. Each year an upgrade of compnents can be postponed the 1<sup>st</sup> year value is spared for the DSO. However as upgrading of components is solution No 1. to the DSO delivering 100% quality in supply, and bearing in mind that the DSO also got to have its cut of the spared costs, the price the DSO will be willing to pay, will be somewhat below 100% of this 1<sup>st</sup> year value on upgrading.

#### EXAMPLE:

If upgrading of a 10 kV feeder costs 2,000,000 DKK, the life-expectancy of this upgrade is 40 year, the inflation is 1% and an interest-rate of 5%, there will be the following value in deferral of grid upgrade, of which some can be used for the necessary flexibility product un-locking the possibility of the deferral.



In Figure 19 the value of deferred investment in grid upgrade is chosen, given the assumptions above. From this it can be seen that the value of the 1<sup>st</sup> year of deferral is approx. 75,000 DKK. From this knowledge the DSO could for instance decide that 40,000 DKK / year can be used to invest in a flexibility product, and from this save the value of 75,000 DKK / year, giving a total surplus of 35,000 DKK / year for the DSO.

If the Aggregator can mobilize the requested flexibility by the DSO at a cost of 40,000 DKK / year, or below, they should be able to make an agreement that the DSO, Aggregator and consumers can benefit from.

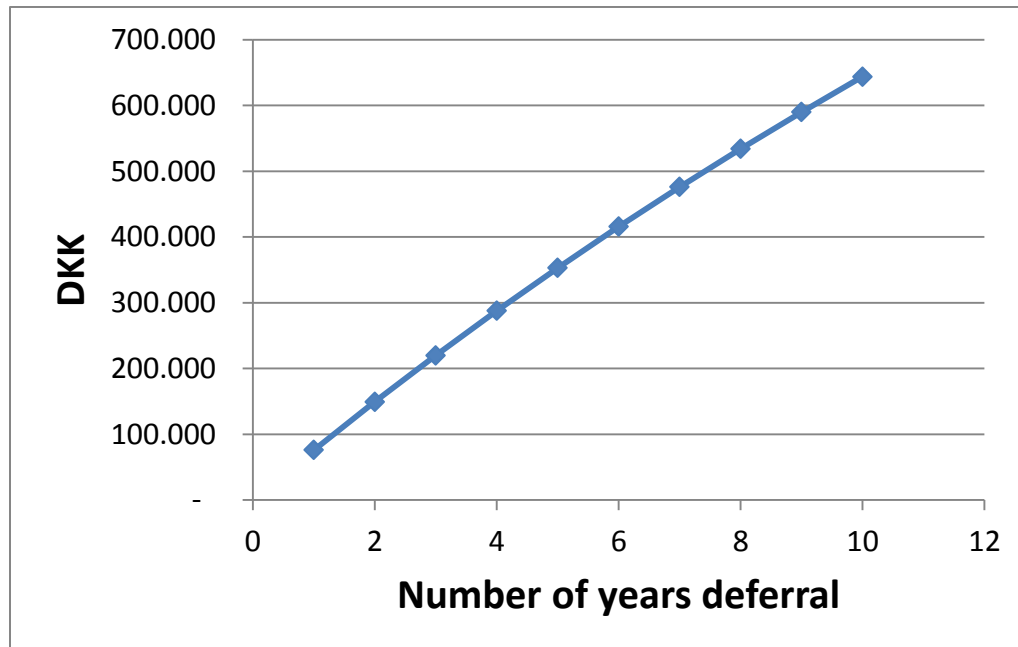


Figure 19: Example of deferred investment in grid upgrade given the number of years deferral.

Additional to this, there could be a substantial value to the DSO in the case where load has increased faster than expected when building the grid infrastructure, as illustrated in case 1 (see section 4.1). In this case there could be a high value in the immediate depreciation made, when replacing a transformer or a cable earlier than the planned lifetime. This is illustrated in Figure 20.

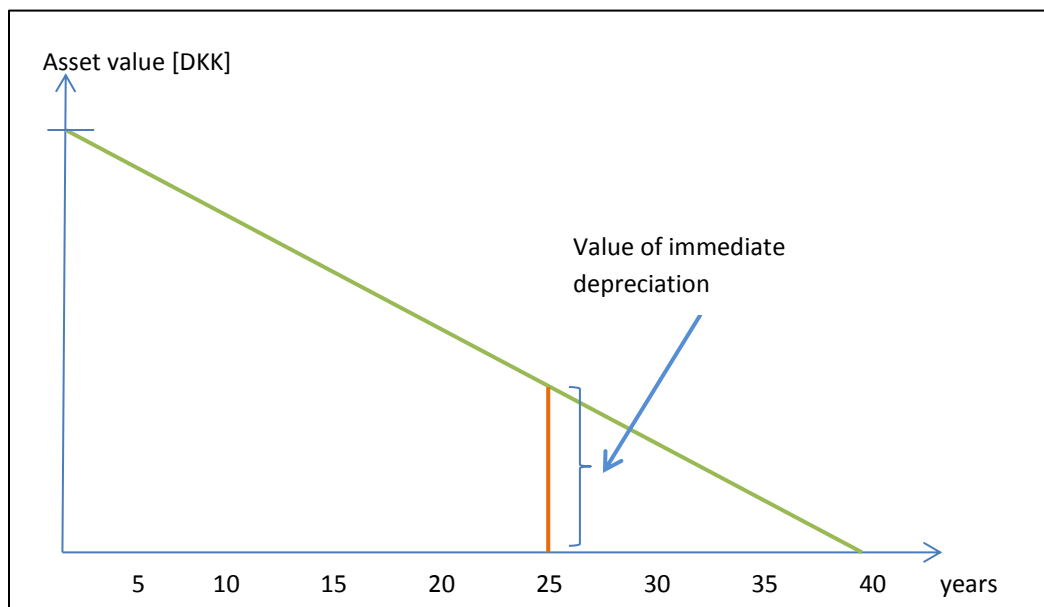


Figure 20: Illustration of value of immediate depreciation (linear)

### 5.1.2 CONTRACTUAL POSSIBILITIES

For each of the flexibility products described in section 5.3.1 - 5.3.4 there could be numerous contractual setups. E.g. could flexibility product no. 2, 3 and 4 be contracted as a X-times fare-ticket, where each activation has a certain cost for the DSO, this is illustrated in Figure 21 below.

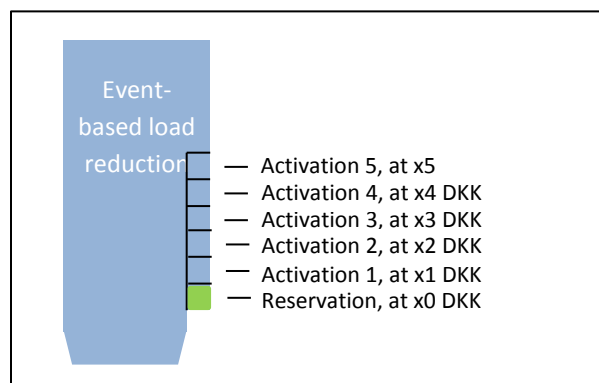


Figure 21: Illustration of five-times fare-ticket.

Several other contractual setups could be suggested. E.g. for flexibility product number 4, if the Aggregator guarantee not to use more power than xx kW in this area for this period of time, the DSO will pay the Aggregator a firm price of yy DKK.

This stresses that value from flexibility for the DSOs, could be realised even in very simple contractual setups, which emphasizes that Smart Grid doesn't have to be complex,

The important result in this section is that flexibility products for the DSO, can be conceptualised, so that it is more tangible how flexibility for the DSOs could be contracted and traded. Flexibility products can for sure be used to increase utilization of grid infrastructure.

### 5.1.3 POSSIBLE TIMELINE IN CONTRACTING FLEXIBILITY PRODUCTS

The timeline in contracting and serving flexibility products are rather simple and illustrated in Figure 22. As a part of the year-ahead planning at the DSOs, the possibility of using flexibility contracts will be considered. For the local grid areas where DSOs can see substantial benefits in demanding a DSO-product, the DSO posts his demands at FLECH, with a deadline for Aggregators to provide offers. On the basis of this, offers will arrive from interested Aggregators, and contracts are made. All of this will be done approx. on a year-ahead basis. Closing in on the contractual period the Aggregators ability to deliver the contracted DSO-service could be tested. Finally the contractual period will come and the DSO will in this activate DSO-products as specified in the contract. After the contracting period has ended, settlement between the DSO and the Aggregator will be carried out and the mutual contractual obligations have been completed.

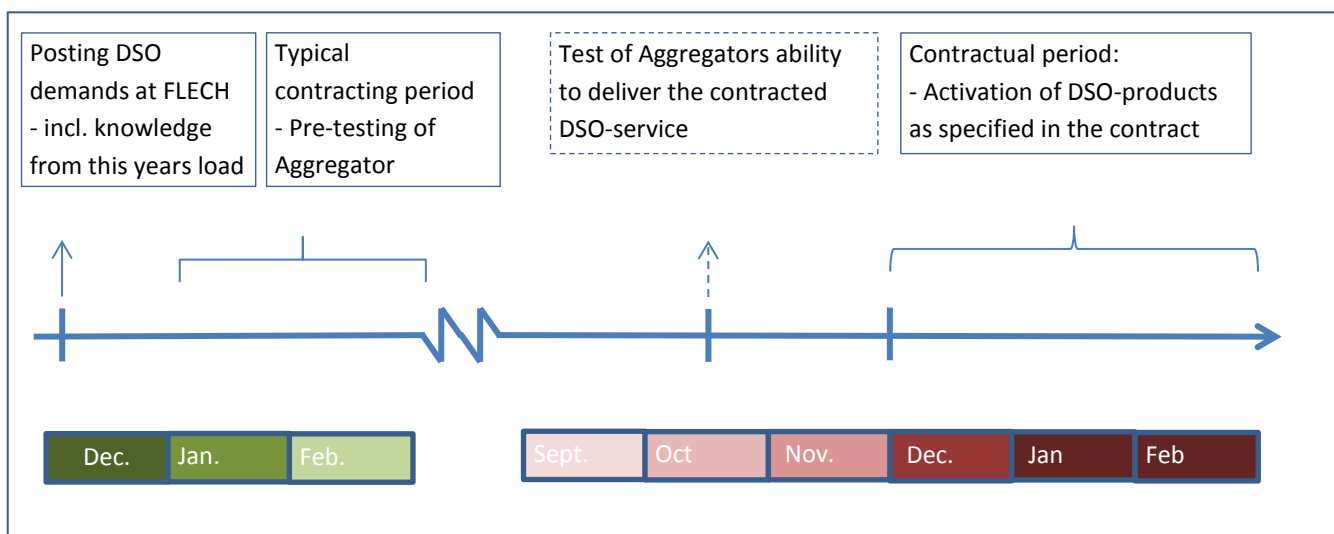


Figure 22: Illustration of the year-ahead timeline in contracting flexibility products

## 5.2 INTRODUCTION OF PRODUCT SPECIFICATIONS

On the basis of the cases described in section 4, possible flexibility products of interest of the DSOs, are described within this section. For each product it is important to specify a set of contractual prerequisites such as:

1)	Service name
2)	Contract valid from
3)	Contract valid until
4)	Est. no. of activations during period
5)	Size of service in power (kW)
6)	Size of service in energy (kWh)
7)	Max. duration of service per activation (h)
8)	On - Trigger
9)	Off - Trigger
10)	Geography (specified by unique consumer numbers)
11)	Maximum allowed activation time
13)	Quality in supply
14)	Pricing (DSO pays Aggregator)
15)	Estimated price per activation
16)	Risk issues
17)	Penalty if failed supply
18)	Other

**Table 1: Overview of basis contractual prerequisites of DSO-products.**

For each of the described products in the following sections, a set of contractual prerequisites will be specified. Three different types of products are suggested relevant or interesting to the DSOs

Below the DSO-Products are divided into 2 categories:

- 1) Products for Load management
- 2) Products for Voltage management

As for the products for voltage management these are provided to put it into perspective. It is not expected that the DSOs either see a need for them in the near future or are ready to rely on these. At present DSOs surely expect to start trying DSO-products, in regard of load management. But on medium and long term products for voltage support could become of interest, if DSOs have gained confidentiality in using DSO-products for load management.

## 5.3 PRODUCTS FOR LOAD MANAGEMENT

### 5.3.1 PRODUCT SPECIFICATION NO 1: POWERCUT PLANNED

The flexibility product, here called “PowerCut Planned” is used to handle the predictable peak loads for periodically daily capacity issues. This is illustrated in Figure 23.

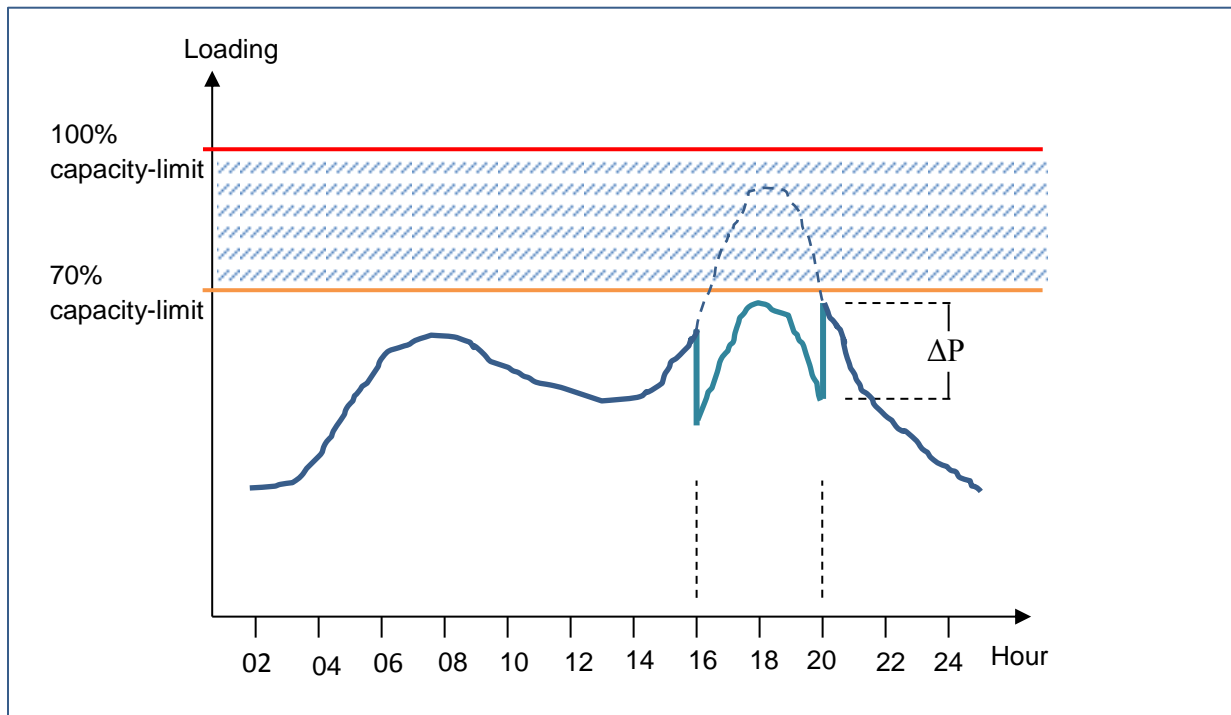


Figure 23: Illustration of product no. 1: *PowerCut Planned*.

To elaborate on this: In the winter months of the year, the distributions grids usually experience the highest loads. Furthermore the daily load patterns are usually rather predictable at least at 10 kV level and above, if hourly load data are available. Thorough knowledge on the daily load patterns at the highest loaded feeders, will make the DSOs able to define, more or less, to what extent daily load reduction would be needed hour-by-hour, at each feeder.

When having good statistics of the remaining consumption in the area of interest, the DSO can reassure itself that their capacity limits most likely won't be violated. But with this product the DSO actually aren't guaranteed that the remaining non-flexible resources might lead to a violation of the capacity limits.

However from this knowledge the DSO will be able to specify the prerequisites on buying “PowerCut Planned” at each feeder. In Table 2 an example on the specified prerequisites on an agreement on delivery of “PowerCut Planned” at an example feeder.

1)	Service name	“PowerCut Planned”
2)	Contract valid from	1 December 2014
3)	Contract valid until	31 February 2015
4)	Est. no. of activations during period	60
5)	Size of service in power (kW)	50
6)	Size of service in energy (kWh)	200 kWh per activation
7)	Max. duration of service per activation (h)	4 hours
8)	On - Trigger	Monday-Friday at 4:00 PM
9)	Off - Trigger	Monday-Friday at 8:00 PM or by request from DSO
10)	Geography (specified by unique consumer numbers)	24000-24791 + 25031
11)	Maximum allowed activation time	N/A – (Firm activation time, see 8))
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min. per day</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 15 min. per day</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 3</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 1,000 DKK / kW = 50,000 DKK for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 830 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- faulted communications or control systems between Aggregator and DERs</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 10,000 DKK / per failed delivery within quality limits</li> <li>- 4 times of failed delivery → termination of the contract</li> </ul> (Average value of life-time reduction of components etc. + administration + mobile power plants)
18)	Other	

Table 2: Example of specified prerequisites on an agreement on delivery of flexibility product no. 1: “PowerCut Planned”.

The advantage of this product is that it is very simple. The three primary technical specifications are:

- 5) Size of service in Power (kW)
- 7) Max. duration of service per activation (h)
- 8) On - Trigger

However the disadvantages are that:

- The consumers will be affected to some extent each Monday-Friday during a three month period of time, in the evening hours.
- The payment divided between the Aggregator and the affiliated consumers are likely to lead to somewhat low remuneration, per activation, as this type of product implies several planned activations during the duration of the contract.

---

#### 5.3.1.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for this service might be a difficult task for the Aggregator, as the remuneration per activation might be rather low per affiliated consumer. However with sufficient consumers involved each consumers experience of having been load shifted might be minimal.

---

#### 5.3.1.2 ACTIVATION SPECIFICATIONS

For this product: "PowerCut Planned", the specifications on activation are very simple. According to the contract the Aggregator activates the agreed service at the specified time, all of the relevant days, unless the Aggregator has heard any other instructions from the DSO.

---

#### 5.3.1.3 QUALITY SPECIFICATIONS

The quality in supply can vary from contract to contract. The quality prerequisites are set by the DSO in order to define the minimum acceptable quality in supply. These specifications should be set in order for the DSO to avoid high alternative costs, when the supply was needed but not supplied.

For this product 100% reliability will be wanted, however should the Aggregator fail to supply, the assets will not be overloaded due to the fact that, both reserve capacity between the 70%-100% limits and short-term overload capacity, are still unused.

Therefore a 95% reliability in supply could most likely be sufficient. It should be considered how to value this, when specifying the payment for this product.

However quantification of the quality will be needed. Practically that could be done by stating specific quality parameters. As an example 4 specific quality parameters are given below:

- a) Deviation in max. duration: +/- 5 min. per day
- b) Deviation from, On - Trigger: +/- 15 min. per day
- c) Deviation in size of service: Max. +/- 2 kW deviation
- d) Acceptable no. of unsuccessful activations: 3

---

#### 5.3.1.4 PENALTY SPECIFICATIONS

If the Aggregator and his affiliated consumers fail to supply as agreed upon within the contract, the payment for providing the flexibility services should be withdrawn in the final payment, according to what has been agreed upon in the contract.

Valuation of the penalty should ideally be cost-true containing: average value of life-time reduction of components etc. + administration + possible use of mobile power plants

However more practically the penalty could be set as:

- a) 10,000 DKK / per failed delivery within quality limits
- b) 4 times of failed delivery leads to termination of the contract and no payment will be made (not even on earlier successful activations)

---

#### 5.3.1.5 PRICE SETTING OF THE FLEXIBILITY PRODUCT

The payment setup on Flexibility product no.1 could be several. However the most likely one is expected to be:

1. A firm payment for the entire contract, paid for at the end of the contracting period.



### 5.3.2 PRODUCT SPECIFICATION NO 2: “POWERCUT URGENT”

The basic thought in regard to flexibility product no. 2: “PowerCut Urgent”, is that according to a contract between the DSO and the Aggregator, the Aggregator reduces his load by a  $\Delta P$ . The Aggregator does this on the basis of a trigger signal sent from the DSO, when the DSO decides that regulation is needed, in order to avoid a congestion situation.

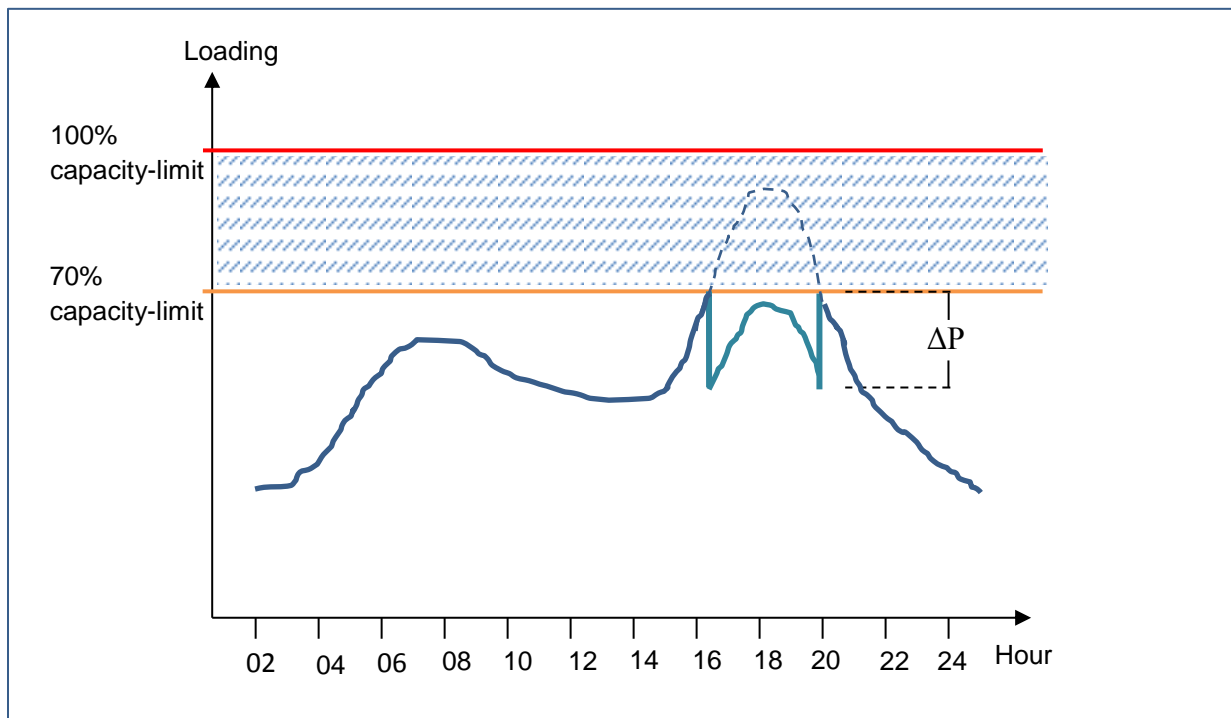


Figure 24: Illustration of product no. 2: *PowerCut Urgent*.

At first glance this product looks much like flexibility product no. 1. However, the important difference is that this product is based on events. Due to this it is likely that this product will be activated fewer times than flexibility product no. 1, as it only gets activated when needed, whereas flexibility product no. 1. will be activated every day of the contract period.

The volume of the reduced energy consumption will also be smaller, due to less activation, but also due to more timely activation, not starting before it becomes absolutely necessary. This means that the chance that the consumers will experience to be activated less often than in flexibility product no. 1, and perhaps with the same payment.

In Table 3 an example on the specified prerequisites on an agreement on delivery of “PowerCut Urgent” at an example feeder.

1)	Service name	"PowerCut Urgent"
2)	Contract valid from	1 December 2014
3)	Contract valid until	31 February 2015
4)	Est. no. of activations during period	40
5)	Size of service in power (kW)	50
6)	Size of service in energy (kWh)	-
7)	Max. duration of service per activation (h)	3 hours
8)	On - Trigger	Signal from the DSO
9)	Off - Trigger	3 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	27030-27791 + 28031
11)	Maximum allowed activation time	15 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 10 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 3</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 10,000 DKK in reservation payment + 1000 per activation = estimated to 40,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 1250 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- faulted communications or control systems between Aggregator and DERs</li> <li>- Faulted communication of trigger signal between Aggregator and DSO</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 10,000 DKK / per failed delivery within quality limits</li> <li>- 4 times of failed delivery → termination of the contract (Average value of life-time reduction of components etc. + administration + mobile power plants)</li> </ul>
18)	Other	

Table 3: Example of specified prerequisites on an agreement on delivery of flexibility product no. 2: "PowerCut Urgent".

---

#### 5.3.2.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for product no. 2 should be easier than in flexibility product no. 1, as the volume of the reduced energy consumption will be smaller. Meaning that the chance that the consumers will experience the reduction will be smaller than in flexibility product no. 1.

---

#### 5.3.2.2 ACTIVATION SPECIFICATIONS

For flexibility product no. 2: "PowerCut Urgent" the specifications on activation are more complex than for flexibility product no. 1. According to the contract the Aggregator must activate the agreed service when receiving a trigger signal from the DSO. This means that the DSO (manual or computer systems) have to both monitor the loads more closely, and send activation signals to the Aggregator when the service is needed. The Aggregator then activates the load reduction, according to the agreed  $\Delta P$ .

This activation procedure is dependent on the communication lines between the Aggregator and the DSO not getting interrupted. The possibility that the communication lines should be interrupted at the event leading to an activation are however very low.

---

#### 5.3.2.3 QUALITY SPECIFICATIONS

As for flexibility product no. 2, a 100% reliability will be wanted by the DSO. However should the Aggregator fail to supply, the assets will not be overloaded due to the fact that both reserve capacity between the 70%-100% limits and short-term overload capacity are still unused.

Therefore a 95% reliability in supply could most likely be sufficient. It should be considered how to value this, when specifying the payment for this product.

See Table 3 for an example of quality specifications.

---

#### 5.3.2.4 PENALTY SPECIFICATIONS

Valuation of the penalty will be similar to what has been described for flexibility product no. 1, see section 5.3.1.4.

---

#### 5.3.2.5 PRICE SETTING OF THE FLEXIBILITY PRODUCT

The payment setup on Flexibility product no.2: “PowerCut Urgent” could be several. However the most likely ones are expected to be:

1. A reservation payment to stand ready + a payment for each activation
2. A firm payment for the entire contract paid for at the end of the contracting period.

The payment is recommended to be done at the end of the period due to the DSOs risk of the Aggregator ignoring or not being able to deliver according to the supply specifications of the contract.

### 5.3.3 PRODUCT SPECIFICATION NO 3: "POWER RESERVE"

The thought in regard to flexibility product no. 3: "PowerReserve", are that the DSOs with this product will be able to exploit the reserve-supply capacity between the 70% and 100% capacity limits, in the everyday normal operation. This will be a huge expansion of the available capacity for normal operation.

However, in order to un-lock this expansion of available capacity it is necessary to be able to reduce loads when facing a reserve-supply situation.

The DSO will most likely activate this flexibility product on rare occasions as it will only be needed when a 10 kV feeder get faulted during exactly the hours of day (and year) with load exceeding the 70% capacity limit. Estimates on this are given as an average of 3 activations per year.

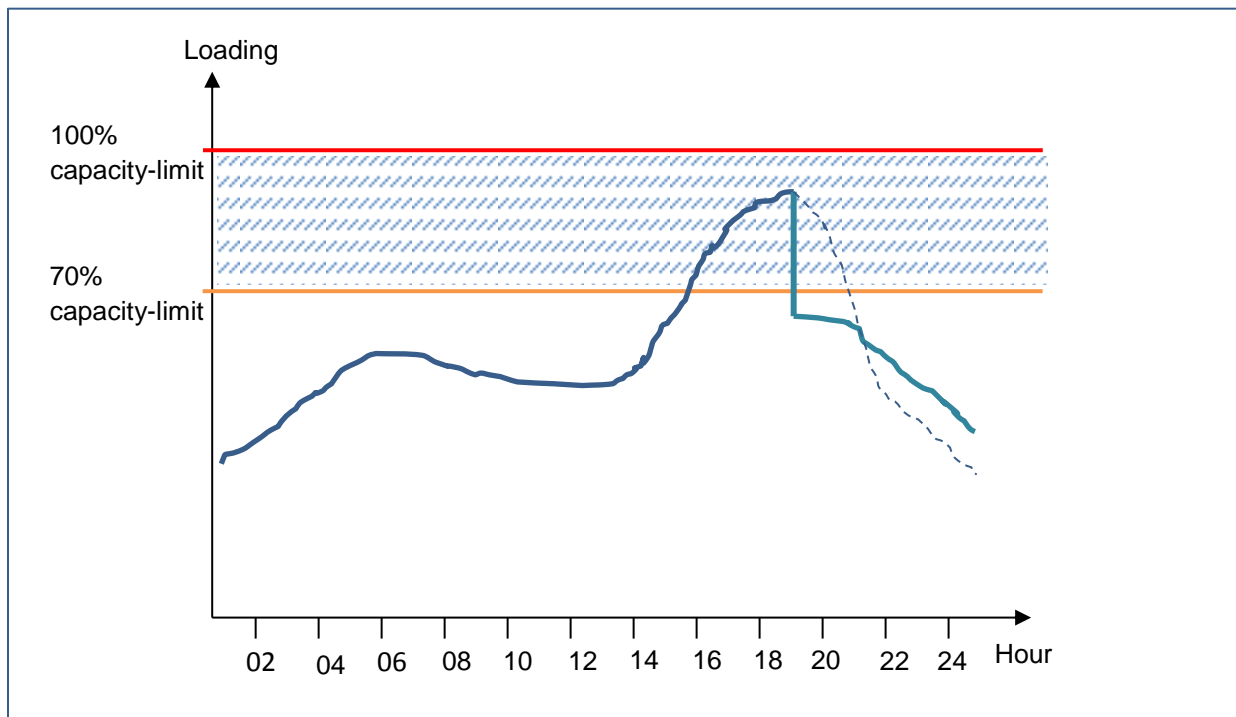


Figure 25: Illustration of product no. 3: *PowerReserve*.

In Table 4 an example on the specified prerequisites on an agreement on delivery of flexibility product no 3 "PowerReserve" at an example feeder.

1)	Service name	"PowerReserve"
2)	Contract valid from	1 Dececeember 2014
3)	Contract valid until	31 February 2015
4)	Est. no. of activations during period	3
5)	Size of service in power (kW)	150
6)	Size of service in energy (kWh)	-
7)	Max. duration of service per activation (h)	3 hours
8)	On - Trigger	Signal from the DSO
9)	Off - Trigger	3 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	42080-46791
11)	Maximum allowed activation time	5 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 1</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 20,000 DKK in reservation payment + 10,000 per activation = estimated to 30,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 16,700 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- Faulted communications or control systems between Aggregator and DERs</li> <li>- Faulted communication of trigger signal between Aggregator and DSO</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 20,000 DKK on 1<sup>st</sup> failure in delivery within quality limits</li> <li>- 2 times of failed delivery → termination of the contract</li> </ul>
18)	Other	

Table 4: Example of specified prerequisites on an agreement on delivery of flexibility product no. 3: "PowerReserve".

---

#### 5.3.3.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources, which on average only need to be activated once a year, sounds easy. However, some challenges will occur from this. Being activated only on rare occasions might lead to failure in supplying the service, due to unmaintained communication and control systems, or the fact that the systems are shut of due to lack of knowledge of the agreement. This challenge might increase if the supplier is an Aggregator having several resources delivering the flexibility service.

On the other hand if the resources are used for supplying several other flexibility services the case of unmaintained systems might not be imminent.

---

#### 5.3.3.2 ACTIVATION SPECIFICATIONS

As the DSO by buying this flexibility product has allowed the loading of the 10 kV feeders to exceed beyond the 70% capacity limit but still below the 100% capacity limit, the DSO is dependent on fast activation of the flexibility service when needed. However, the specification on activation time for this flexibility product is linked with how fast the DSO is able to recouple their 10 kV feeders for reserve-supply. From experience within time used for recoupling, activation time for this flexibility service could be as long as 30 sec. from the instant when the request from the DSO is received. However as the DSO in case 2 are facing a reserve supply situation, some re-couplings in the grid has to be made to obtain the reserve supply coupling setup, for the specific situation. These re-couplings will take some time, at present they are mostly manually made implying a re-coupling time of at least 15 min. or so. However, in the future re-couplings are likely to be made remote and therefore re-coupling time can be limited to a few minutes.

The maximum allowable reaction time for this type of flexibility product is therefore expected to be approx. 3 min. The flexibility service will most likely only be needed for duration of approx. 3-4 hour each time it is used, as either the fault has been dealt with or the consumption has lowered due to the day-variation load curve.

---

#### 5.3.3.3 QUALITY SPECIFICATIONS

This flexibility product might only be activated on rare occasions, however, the need for having them delivered in these occasions will practically be 100%. Although the DSO can exceed the 100% capacity limit for some hours (by short-term loading, which in return will reduce the statistical life-time of cables and transformers) it is assessed that it will not likely be part of a strategic choice from the DSO. Therefore it is expected that high requirements on quality of supply will be set on flexibility product no. 3.

For an example see Table 4.

---

#### 5.3.3.4 PENALTY SPECIFICATIONS

If the requirements on quality of supplying this flexibility product cannot be complied with, the DSO risks to go beyond short-term overloading of his assets, and thereby reducing the life-time of the assets. This life-time reduction has a price tag. The penalty of not supplying this flexibility product should therefore be higher than the cost of life-time reduction incl. earlier entrepreneurial work and administration. Calculation of an average value of life-time reduction for 10 kV feeders, transformers etc. might be possible. This should then be used as a standard penalty for all agreements of this flexibility product.

In this case it is suggested that a single chance will be given, leading to the following penalty specifications:

- a) 20,000 DKK on 1<sup>st</sup> failure in delivery within quality limits
- b) 2<sup>nd</sup> failure in delivery → termination of the contract and no payment will be made (not even on earlier successful activations)

---

#### 5.3.3.5 PRICE SETTING OF PRODUCT

The payment setup on Flexibility product no.3: “PowerReserve” could be several. However, the most likely ones are expected to be:

1. A reservation payment to stand ready + a payment for each activation
2. A firm payment for the entire contract paid for at the end of the contracting period.

In Table 4 option 1 are suggested.



### 5.3.4 PRODUCT SPECIFICATION NO 4: "POWERCAP"

The basic thought in regard to flexibility product no. 4: "PowerCap" is that this flexibility product will ensure the DSO that a capacity limit specified by the DSO will not be violated. This gives the DSO a valuable certainty that the feeder of interest will never be higher loaded than specified by the DSO.

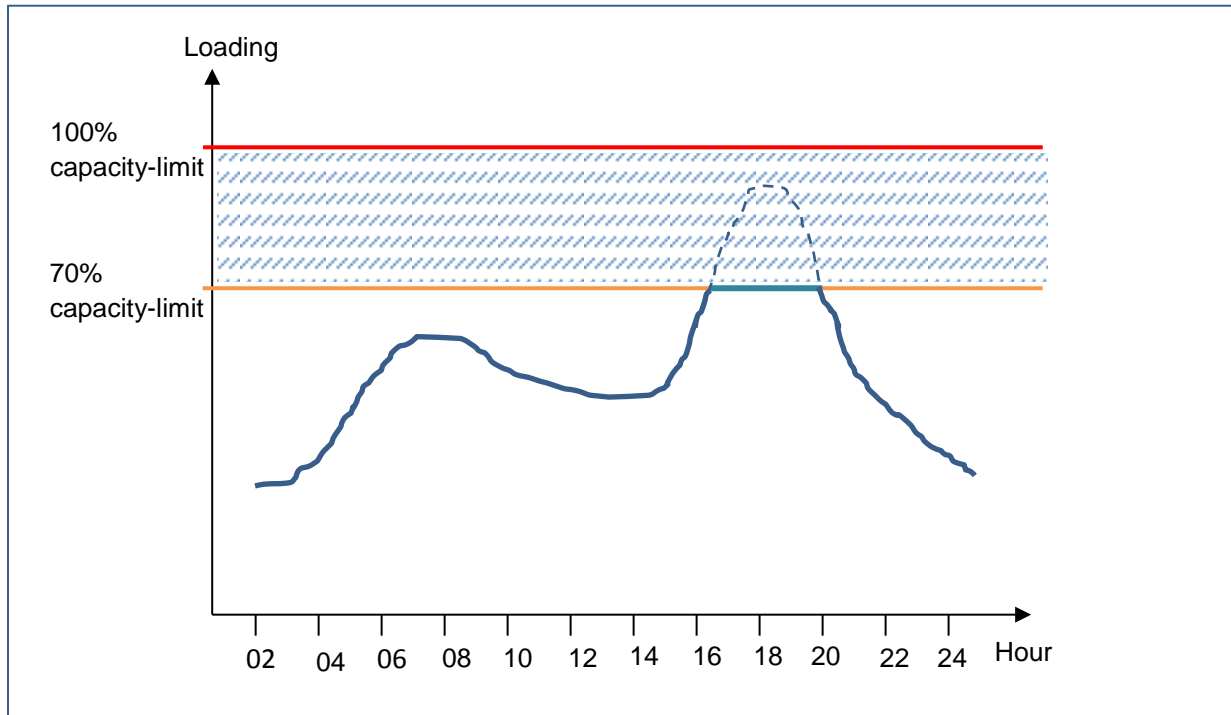


Figure 26: Illustration of product no. 4: *PowerCap*.

The challenging thing of flexibility product no. 4 is that the control of the load reduction of the DERs is dependent on the DSO sending a reference signal e.g. every 30 sec. on the present loading of the feeder. On the basis of this reference signal, the Aggregator runs a close-loop control of the DER ensuring that the load will not exceed the capacity limit agreed upon. This closed loop is illustrated in Figure 27.

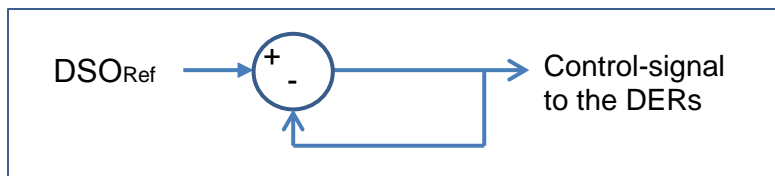


Figure 27: Illustration of the Aggregators closed loop control, with reference signal from the DSO to the Aggregator.

In the case where several Aggregators are jointly providing the “PowerCap” product, a corresponding closed-loop control will be applicable, where a signal will go to all the contracted Aggregators corresponding to each aggregator’s proportional share of the DSO-product delivery.

Alternatively one Aggregator holds the main contract and have sub-aggregators to help him in creating the product specified by the DSO. In this case a solution could also be that the Aggregator holding the main contract will forward the signal, at the right proportional ratio to his, in this case, affiliated sub-aggregators. However this might pose a delay in the arrival of the signal to the sub-aggregators.

It is crucial for this closed-loop control that communication between the Aggregator and the DSO works without interruption, in the case of an event.

In Table 5 is an example of the specified prerequisites on an agreement on delivery of “PowerCap” at an example feeder.

1)	Service name	"PowerCap"
2)	Contract valid from	1 December 2014
3)	Contract valid until	31 February 2015
4)	Est. no. of activations during period	40
5)	Size of service in power (kW)	N/A
6)	Size of service in energy (kWh)	N/A
7)	Max. duration of service per activation (h)	3 hours
8)	On - Trigger	Signal from the DSO
9)	Off - Trigger	3 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	31080-34891
11)	Maximum allowed activation time	10 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 20,000 DKK in reservation payment + 1000 per activation = estimated to 40,000 DKK for the entire contract period.</li> <li>- In total 60,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 1,500 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- Faulted communications or control systems between Aggregator and DERs</li> <li>- Faulted communications between Aggregator and DSO</li> <li>- Faulted communication of trigger signal between Aggregator and DSO</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 15,000 DKK on 1<sup>st</sup> failure in delivery within quality limits</li> <li>- 25,000 DKK on 2<sup>nd</sup> failure in delivery within quality limits</li> <li>- 3 times of failed delivery → termination of the contract</li> </ul>
18)	Other	DSO will continuously (every 30. sec.) send a reference signal to the Aggregator during every event.

Table 5: Example of specified prerequisites on an agreement on delivery of flexibility product no. 4: "PowerCap".

---

#### 5.3.4.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for flexibility product no. 4 are expected to be much easier like in flexibility product no. 2. The payment per activation are limited, however less energy in terms of kWh is to be reduced in flexibility product no. 4, compared to flexibility product no. 1 and 2. Meaning that the consumers might not experience the activation.

---

#### 5.3.4.2 ACTIVATION SPECIFICATIONS

As the Aggregator might not have an agreement with all consumers connected to the feeder, the Aggregator has to make advanced control of his affiliated consumer's DERs. This control is dependent on a continuous reception of a reference-signal from the DSO, with minimal delay or interruption in the communication between the Aggregator and DSO, and between the Aggregator and the DERs. This makes Flexibility product no 4 the most advanced of the suggested products.

---

#### 5.3.4.3 QUALITY SPECIFICATIONS

High quality in supply will of course be wanted by the DSO. However should the Aggregator fail to supply, the assets will most likely not be overloaded due to the fact that both reserve capacity between the 70%-100% limits and short-term overload capacity are still unused.

Therefore the DSO might be open to accept a few times of failure in supply, of Flexibility product no. 4. It should however be considered how to value this, when specifying the payment for this product. In the following section 5.3.4.4 thoughts on this are discussed.

---

#### 5.3.4.4 PENALTY SPECIFICATIONS

The penalty of not supplying within the quality specification should as mentioned in earlier sections take basis in the associated cost e.g.: Average value of life-time reduction of components etc. + administration + possible use of mobile power plants.

However this value will be individual on each feeder. Therefore a more general penalty might be more feasible in real life. In the example of Table 5, it is suggested that the contract will be terminated in case of 3 failures in supply. The penalty on the 1<sup>st</sup> failure is here suggested to be 15,000 DKK, and raised to 25,000 DKK on the 2<sup>nd</sup> failure to stress the importance of steady supply.

---

#### 5.3.4.5 PRICE SETTING OF THE PRODUCT

As for Flexibility product no. 2 and 3, the payment setup on Flexibility product no.4: “PowerCap” could be several. However the most likely ones are expected to be:

1. A reservation payment to stand ready + a payment for each activation
2. A firm payment for the entire contract, paid for at the end of the contracting period.

Where option 1. is the one suggested in Table 5.

### 5.3.5 PRODUCT SPECIFICATION NO 5: "POWERMAX"

The flexibility product "PowerMax", are somewhat similar to the "PowerCap" product. The basic thought in regard of the "PowerMax" product is that by buying "PowerMax" the DSO can be ensured that the Aggregator ensures that his local portfolio of DERs will not exceed XX MW, during the activation periods.

Whereas in "PowerCap" the Aggregator would ensure that the DSOs capacity limits where not violated, "PowerMax" is more simple as the Aggregator in this way only is obliged to ensure that his own local portfolio will not exceed XX MW, during the activation periods. However this implies that for the DSO to use this product, the DSO needs to be able to make qualified prognosis of the consumption of both managed and unmanaged loads, and from this can state the right amount of help needed, knowing that the unmanaged loads will not chance consumption pattern.

In Figure 28, the DSO-product: "PowerMax", is illustrated. However, the effect on the total load, which is the one showed, will be dependent on whether the Aggregator's portfolio is increasing its consumption at the time of activation, or if the portfolio are running at a higher load level than expected and therefore are lowered to the agreed level. The first case is illustrated in Figure 28. The latter case will probably lead to a consumption-curve dropping to a certain level, e.g. mirrored on a horizontal axis.

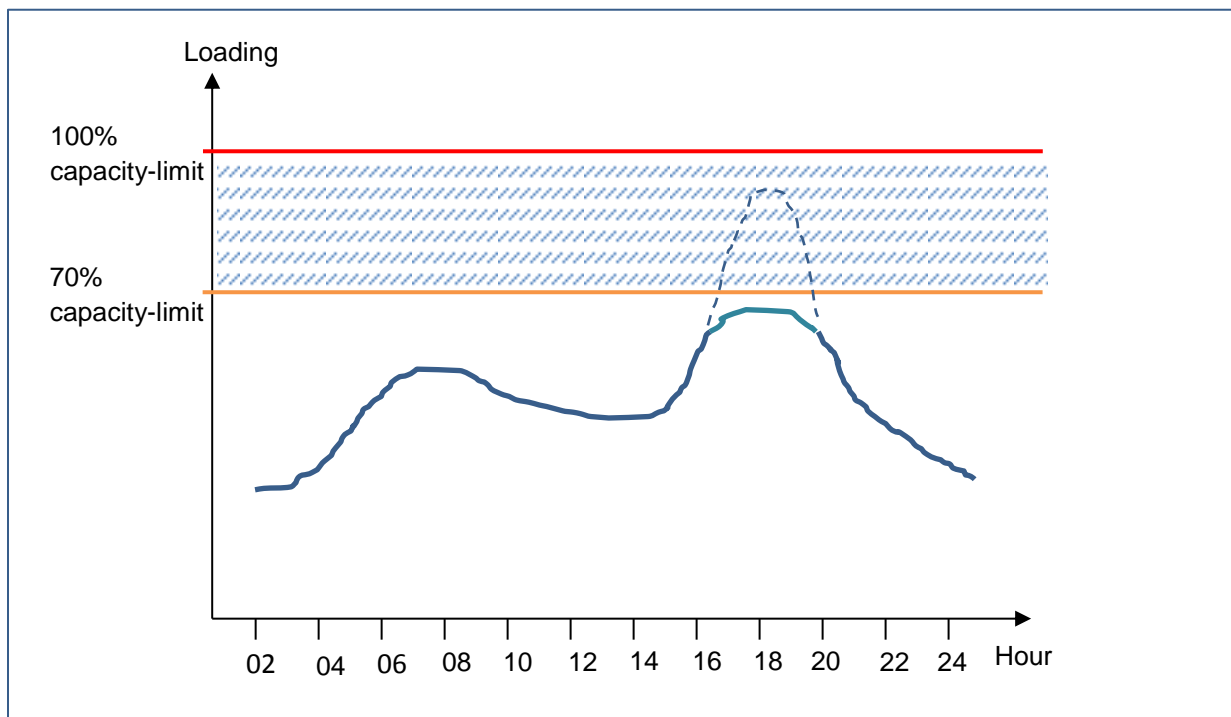


Figure 28: Illustration of product no. 5: *PowerMax*.

“PowerMax” will likely have the similar technical interest to the DSOs, as “PowerCut” products, as the DSO in both cases has to make a local forecast of buying the DSO-products will be sufficient to handle their situations. However “PowerMax” might be cheaper for the Aggregator to offer, as less energy is differed and as load management of the Aggregator’s local portfolio is possible to a wider extent.

1)	Service name	“PowerMax”
2)	Contract valid from	1 December 2014
3)	Contract valid until	31 February 2015
4)	Est. no. of activations during period	60
5)	Size of service in power (kW)	50
6)	Size of service in energy (kWh)	200 kWh per activation
7)	Max. duration of service per activation (h)	4 hours
8)	On - Trigger	Monday-Friday at 4:00PM
9)	Off - Trigger	Monday-Friday at 8:00 PM or by request from DSO
10)	Geography (specified by unique consumer numbers)	324000-324791 + 325031
11)	Maximum allowed activation time	N/A – (Firm activation time, see 8))
13)	Quality in supply	<ul style="list-style-type: none"> <li>- Deviation in max. duration: +/- 5 min. per day</li> <li>- Deviation from, On - Trigger: +/- 15 min. per day</li> <li>- Deviation in size of service: Max. +/- 2 kW deviation</li> <li>- Acceptable no. of unsuccessful activations: 3</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 1,000 DKK / kW = 50,000 DKK for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 830 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- faulted communications or control systems between Aggregator and DERs</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 10,000 DKK / per failed delivery within quality limits</li> <li>- 4 times of failed delivery → termination of the contract</li> </ul> (Average value of life-time reduction of components etc. + administration + mobile power plants)
18)	Other	

Table 6: Example of specified prerequisites on an agreement on delivery of flexibility product no. 5: “PowerMax”.

---

#### 5.3.5.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for this service might be a difficult task for the Aggregator, as the remuneration per activation might be rather low per affiliated consumer. However, with sufficient consumers involved each consumer's experience of having been load shifted might be minimal.

---

#### 5.3.5.2 ACTIVATION SPECIFICATIONS

For this product: "PowerMax", the specifications on activation are very simple. According to the contract the Aggregator activates the agreed service at the specified time, all of the relevant days, unless the Aggregator has heard any other instructions from the DSO.

---

#### 5.3.5.3 QUALITY SPECIFICATIONS

The quality specifications of "PowerMax" will be similar to "PowerCut – Planned", see section 5.3.1.3.

---

#### 5.3.5.4 PENALTY SPECIFICATIONS

The quality specifications of "PowerMax" will be similar to "PowerCut – Planned", see section 5.3.1.4

---

#### 5.3.5.5 PRICE SETTING OF THE FLEXIBILITY PRODUCT

The payment setup on "PowerMax" could be several. However the most likely one is expected to be:

1. A firm payment for the entire contract period.



### 5.3.6 COMPARISON OF DSO-PRODUCTS FOR LOAD MANAGEMENT

Comparing the DSO-products for load management the following mayor differences are identified:

1. DSO-certainty in having solved the load issue
2. Special technical prerequisites at the DSO
3. Operational usage

The differences are listed in Table 7:

	DSO certainty	Special technical prerequisites at the DSO	Operational usage
<b>"PowerCut - Planned"</b>	95%	None	Optimized normal operation
<b>"PowerCut – Urgent"</b>	95%	- Monitoring (Semi on-line) - Fast communication to Aggregator	Optimized normal operation
<b>"PowerReserve"</b>	95%	- Monitoring (On-line) - Fast communication to Aggregator	Reserve supply operation
<b>"PowerCap"</b>	99%	- Monitoring (On-line) - Fast communication to Aggregator - On-line communication of referencesignal	Optimized normal operation
<b>"PowerMax"</b>	90%	None	Optimized normal operation

Table 7: Load management product overview.

## 5.4 PRODUCTS FOR VOLTAGE MANAGEMENT

### 5.4.1 PRODUCT SPECIFICATION NO 6: "VOLTAGESUPPORT"

In regard of serving the DSO's with voltage support, there are two different means that Aggregator can use to ensure that the DSOs stay within the voltage band of: +/- 10% of  $U_{nom}$ .

The correlation between voltage and Active and Reactive power, can for radial topologies (usual for 0.4 and 10 kV grids) be describe by the following equation:

$$V(x) = \left( \frac{V_R + Z_C I_R}{2} \right) e^{\gamma x} + \left( \frac{V_R - Z_C I_R}{2} \right) e^{-\gamma x}$$

Where

$x$  = location / length of the line

$$Z_C = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

And

$$\gamma = \sqrt{(R + j\omega L) \cdot (G + j\omega C)}$$

From this it can be seen that voltage levels can be affected by change in both active and reactive power. The possible change is dependent of the X/R ratio at the specific voltage level, and local feeder, in focus. E.g. the effect on voltage of reducing active power is different at 10 kV level compared to the effect at 0.4 kV level.

With that in mind, products for "VoltageSupport" at different voltage levels will be specifiable, for each 10 kV or 0.4 kV feeder. Although it differs from DSO to DSO, in Figure 29 is illustrated some rule-of-thumb values in dimensioning of distribution grids, with max. allowable voltage drop along 10 kV and 0.4 kV feeders.

The DSO can use these specific values to contract the Aggregator on "VoltageSupport". The Aggregator will from this have to ensure that these voltage limits are not violated.

In future contractual agreements the DSO will most likely be able to have more floating limit (wider limit), with increase measurement, and thereby knowledge of the grid state. The above description should therefore be seen as a first step inspiration to the context of which the product "VoltageSupport" is relevant.

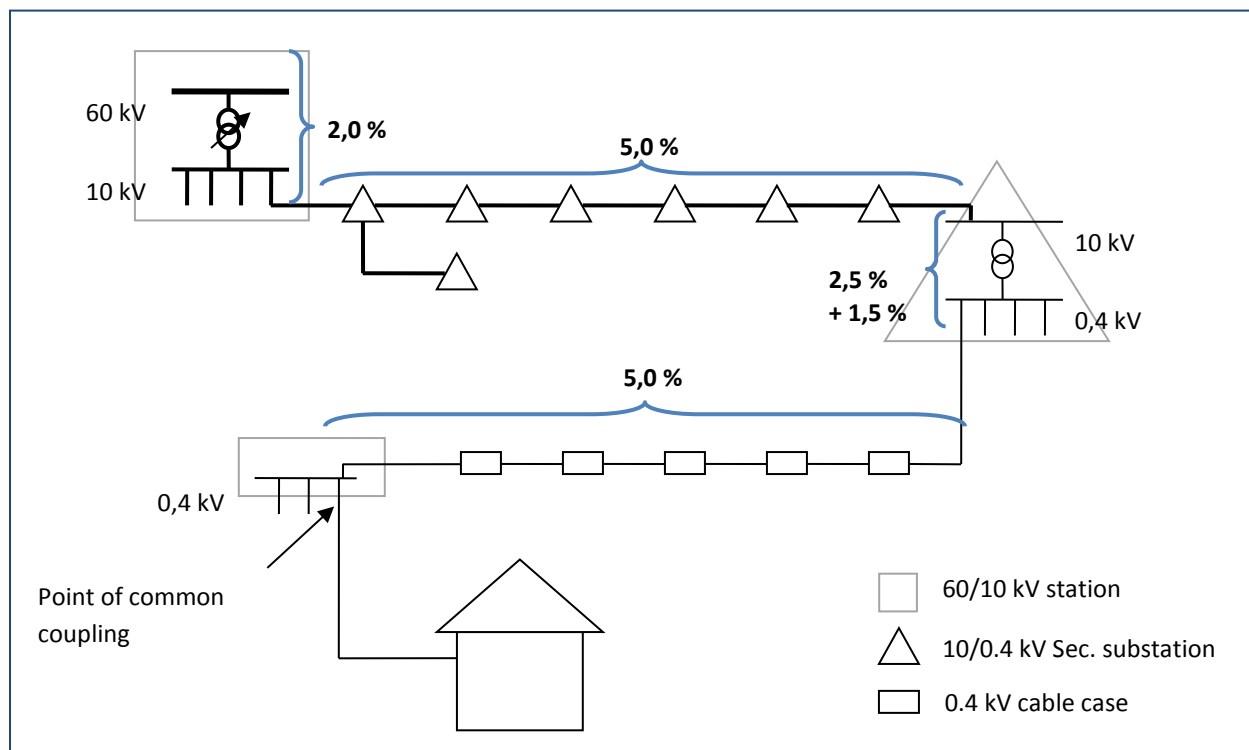


Figure 29. Illustration of rule-of-thumb values in dimensioning of voltage drops in distribution grids.

1)	Service name	"VoltageSupport"
2)	Contract valid from	1 January 2015
3)	Contract valid until	31 December 2015
4)	Est. no. of activations during period	100
5)	Size of service in power (kW)	N/A
6)	Size of service in energy (kWh)	N/A
7)	Max. duration of service per activation (h)	Until critical situation has ended (est. max. 2 hours)
8)	On - Trigger	Signal from the DSO
9)	Off - Trigger	Est. 2 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	261080-265891
11)	Maximum allowed activation time	5 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 1 min.</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 0 DKK in reservation payment + 500 per activation = estimated to 50,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 500 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- Faulted communications or control systems between Aggregator and DERs</li> <li>- Faulted communications between Aggregator and DSO</li> <li>- Faulted communication of trigger signal between Aggregator and DSO</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 15,000 DKK on 1<sup>st</sup> failure in delivery within quality limits</li> <li>- 25,000 DKK on 2<sup>nd</sup> failure in delivery within quality limits</li> <li>- 3 times of failed delivery → termination of the contract</li> </ul>
18)	Other	DSO will continuously (every 30. sec.) send a reference signal to the Aggregator during every event.

Table 8: Example of specified prerequisites on an agreement on delivery of flexibility product no. 6: "VoltageSupport".

---

#### 5.4.1.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for flexibility product no. 6 are not necessarily easy, as it is a rather complex product to explain to the DER owners, both in technical terms but also in regard of possible affect, in case of activation.

---

#### 5.4.1.2 ACTIVATION SPECIFICATIONS

In order to be able to deliver "VoltageSupport" the Aggregator is dependent on a continuously reception of a reference-signal from the DSO, for each contracted 10 or 0,4 kV feeder. This reference signal will specify how close voltage is to exceed the voltage bands, and thereby the needed reaction from the Aggregators affiliated DERs. This reference signal has to be sent with minimal delay or interruption between the Aggregator and DSO, and between the Aggregator and the DERs. This makes Flexibility product no. 6, a rather advanced flexibility product

---

#### 5.4.1.3 QUALITY SPECIFICATIONS

High quality in supply will of course be wanted by the DSO. Should the Aggregator fail to supply (due to mal-function of implication hardware or software), fall-back strategies will be needed as a consequence of too high or too low voltage, at a point of common coupling, imply a risk of causing appliances to mal-function, which will not be neither legally accepted nor accepted by the consumer.

Quality specifications on delivery of this DSO-product will therefore have to be stricter than for products no. 1-5.

---

#### 5.4.1.4 PENALTY SPECIFICATIONS

The penalty of not supplying within the quality specifications should as mentioned in earlier sections be based on the associated costs. However, in the case of DSO-product no. 6 the associated costs will also consist of the value of risking compensation claims for broken appliances. Therefore the penalty will likely comprise of:

- Average value of life-time reduction of components etc. + administration + risk of compensation claims.

This value will be individual on each feeder. A more general penalty might be more feasible in real life. Therefore the principle in specifying the penalty might very well be as simple as for product 1-5, e.g.: The penalty on the 1<sup>st</sup> failure could be 15,000 DKK, and raised to 25,000 DKK on the 2<sup>nd</sup> failure to stress the importance of steady supply.

---

#### 5.4.1.5 PRICE SETTING OF THE PRODUCT

The payment setup on Flexibility product no. 6: "VoltageSupport" could be several. However the most likely ones are expected to be:

1. A firm payment for the entire contract, on continuous delivery during the whole contracted period.
2. A reservation payment to stand ready + a payment for each activation

Where option 1 is seen as the most likely option and therefore suggested in Table 8.

#### 5.4.2 PRODUCT SPECIFICATION NO 7: "VARSUPPORT"

As described in section 4.6 DSOs are subject to carrying out MVar control, in order to stay within certain MVar limit at the exchange point (150/60 kV or 132/50 kV transformers) upward, towards the transmission grid (owned by the TSO).

The usual way of handling this for the DSOs is buying of shunt reactor or capacitor banks. However with increased amounts of decentralized generation (DG), which in addition are getting more and more advanced, the DSO might be able to buy the needed MVar rather cheap from DG units that are already running.

Several DGs are able to control their MVar uptake or output, ranging from medium sized (1-50 MVA) CHP-plants over most of the newer Wind-turbines to PVs.

In Figure 30 to Figure 32, operation areas for Synchronous generator, and two wind turbine types are shown.

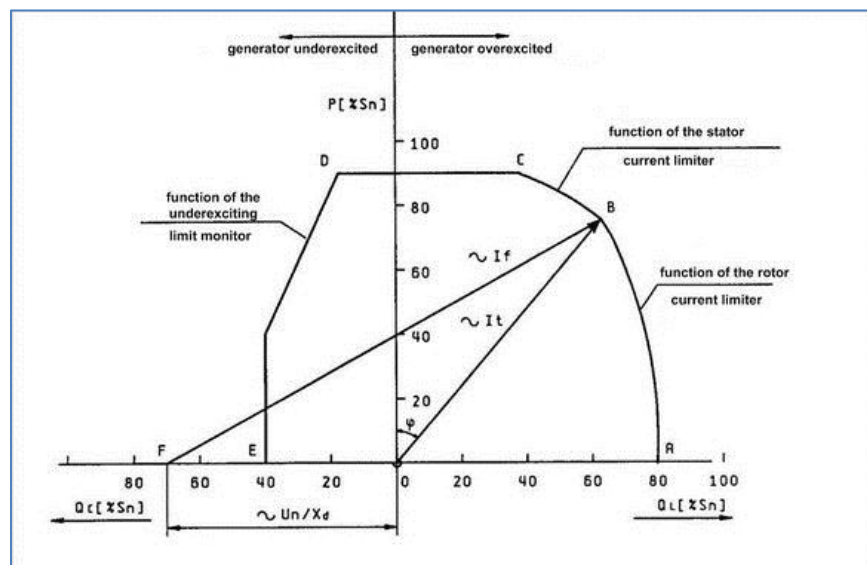


Figure 30: Example of PQ diagram for a synchronous generator. Source [4].

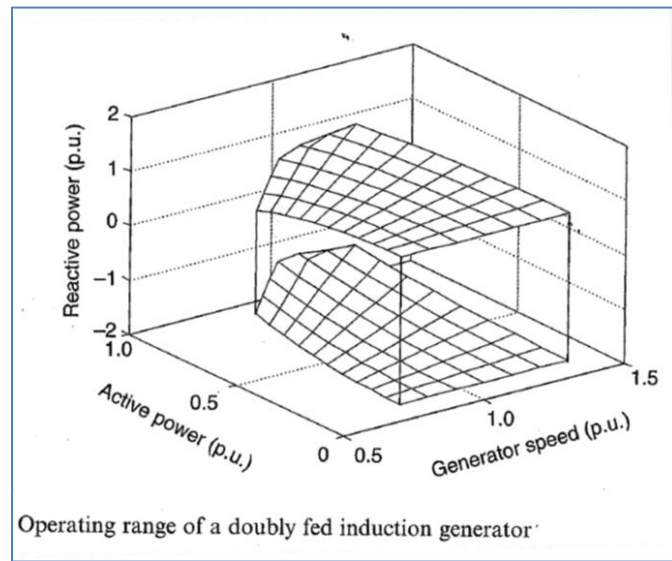


Figure 31: Guiding text. Source [5].

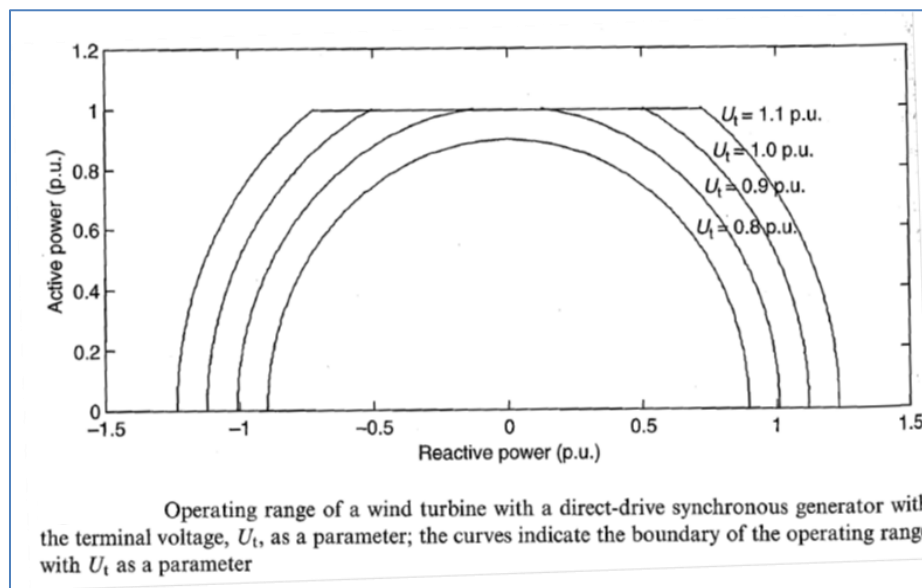


Figure 32: Guiding text. Source [5].

All of these DG types are able to provide MVar support and are in operation in Denmark in vast numbers, at least the two first mentioned. Furthermore, PVs with advanced inverters will also be able to provide MVar-support. If the DGs are able to provide MVar-support sufficiently cheap and reliable, it could likely be of interest to the DSOs.



1)	Service name	"VArSupport"
2)	Contract valid from	1 November 2014
3)	Contract valid until	31 January 2015
4)	Est. no. of activations during period	50
5)	Size of service in power (kW)	N/A
6)	Size of service in energy (kWh)	N/A
7)	Max. duration of service per activation (h)	Until critical situation has ended (est. max. 2 hours)
8)	On - Trigger	Signal from the DSO
9)	Off - Trigger	Est. 2 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	108045-189125
11)	Maximum allowed activation time	5 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 10,000 DKK in reservation payment + 500 per activation = estimated to 25,000 DKK for the entire contract period.</li> <li>- In total 35,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 500 DKK
16)	Risk issues	Failure in supply, due to: <ul style="list-style-type: none"> <li>- Faulted communications or control systems between Aggregator and DERs</li> <li>- Faulted communications between Aggregator and DSO</li> <li>- Faulted communication of trigger signal between Aggregator and DSO</li> </ul>
17)	Penalty if failed supply	<ul style="list-style-type: none"> <li>- 10,000 DKK on 1<sup>st</sup> failure in delivery within quality limits</li> <li>- 15,000 DKK on 2<sup>nd</sup> failure in delivery within quality limits</li> <li>- 3 times of failed delivery → termination of the contract</li> </ul>
18)	Other	

Table 9: Example of specified prerequisites on an agreement on delivery of flexibility product no. 7: "VArSupport".

---

#### 5.4.2.1 MOBILIZATION SPECIFICATIONS

Mobilizing resources for “VArSupport” are not necessarily easy, as it is a rather complex product to explain to the DG owners, both in technical terms but also in regard of possible affect on the DGs operation, in case of activation.

---

#### 5.4.2.2 ACTIVATION SPECIFICATIONS

In order to be able to deliver “VArSupport” the Aggregator shall either achieve a signal as on-trigger at each activation or get at continuous signal to react upon. In regard of the MVar-support it is at present expected to be an on-trigger signal, due to the fact that the volatility in MVar exchange towards the TSO is still rather low.

---

#### 5.4.2.3 QUALITY SPECIFICATIONS

High quality in supply will of course be wanted by the DSO. Should the Aggregator fail to supply (due to mal-function of implication hardware or software), the DSO will most likely only face a penalty from the TSO.

Therefore the DSO might be open to accept a few times of failure in supply, as long as the penalty from the TSO are not higher than the penalty the DSO can pose on the Aggregator, in case of failure in supply. It should be considered how to value this, when specifying the payment for this product. In the following section 5.3.4.4 thoughts on this are discussed.

---

#### 5.4.2.4 PENALTY SPECIFICATIONS

The penalty of not supplying within the quality specifications should be based on the associated costs. Therefore the penalty will likely comprise of:

- Penalty from the TSO to the DSO in not complying to the MVar-limits + administration

---

#### 5.4.2.5 PRICE SETTING OF THE PRODUCT

The payment setup on the Flexibility product: “VArSupport” could be several. However the most likely ones are expected to be:

1. A reservation payment to stand ready + a payment for each activation

## 5.5 PRODUCT SPECIFICATIONS – SUMMARY

### 5.5.1 FLEXIBILITY PRODUCTS FOR LOAD MANAGEMENT - SUMMARY

1)	Service name	"PowerCut Planned"	"PowerCut Urgent"	"PowerReserve"	"PowerCap"	"PowerMax"
2)	Contract valid from	1 December 2014	1 December 2014	1 December 2014	1 December 2014	1 December 2014
3)	Contract valid until	28 February 2015	28 February 2015	28 February 2015	28 February 2015	28 February 2015
4)	Est. no. of activations during period	60	40	3	40	60
5)	Size of service in power (kW)	50	50	150	N/A	50
6)	Size of service in energy (kWh)	200 kWh per activation	-	-	N/A	200 kWh per activation
7)	Max. duration of service per activation (h)	4 hours	3 hours	3 hours	3 hours	4 hours
8)	On - Trigger	Monday-Friday at 4:00 PM	Signal from the DSO	Signal from the DSO	Signal from the DSO	Monday-Friday at 4:00 PM
9)	Off - Trigger	Monday-Friday at 8:00 PM or by request from DSO	3 hours from "on"-signal, or by earlier signal from the DSO	3 hours from "on"-signal, or by earlier signal from the DSO	3 hours from "on"-signal, or by earlier signal from the DSO	Monday-Friday at 8:00 PM or by request from DSO
10)	Geography (specified by unique consumer numbers)	24000-24791 + 25031	27030-27791 + 28031	42080-46791	31080-34891	324000-324791 + 325031
11)	Maximum allowed activation time	N/A – (Firm activation time, see 8))	15 min.	5 min.	10 min.	N/A – (Firm activation time, see 8))

1)	Service name	"PowerCut Planned"	"PowerCut Urgent"	"PowerReserve"	"PowerCap"	"PowerMax"
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min. per day</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 15 min. per day</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 3</li> </ul>	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 10 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 3</li> </ul>	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 1</li> </ul>	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min. per day</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 15 min. per day</li> <li>- <u>Deviation in size of service:</u> Max. +/- 2 kW deviation</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 3</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 1,000 DKK / kW = 50,000 DKK for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>	<ul style="list-style-type: none"> <li>- 10,000 DKK in reservation payment + 1000 per activation = estimated to 40,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>	<ul style="list-style-type: none"> <li>- 20,000 DKK in reservation payment + 10000 per activation = estimated to 30,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>	<ul style="list-style-type: none"> <li>- 20,000 DKK in reservation payment + 1000 per activation = estimated to 40,000 DKK for the entire contract period.</li> <li>- In total 60,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>	<ul style="list-style-type: none"> <li>- 1,000 DKK / kW = 50,000 DKK for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>
15)	Estimated price per activation	- 830 DKK	- 1,250 DKK	- 16,700 DKK	- 1,500 DKK	- 830 DKK

1)	Service name	"PowerCut Planned"	"PowerCut Urgent"	"PowerReserve"	"PowerCap"	"PowerMax"
16)	Risk issues	Failure in supply, due to: - faulted communications or control systems between Aggregator and DERs	Failure in supply, due to: - faulted communications or control systems between Aggregator and DERs - Faulted communication of trigger signal between Aggregator and DSO	Failure in supply, due to: - Faulted communications or control systems between Aggregator and DERs - Faulted communication of trigger signal between Aggregator and DSO	Failure in supply, due to: - Faulted communications or control systems between Aggregator and DERs - Faulted communication of trigger signal between Aggregator and DSO	Failure in supply, due to: - faulted communications or control systems between Aggregator and DERs
17)	Penalty if failed supply	- 10,000 DKK / per failed delivery within quality limits - 4 times of failed delivery → termination of the contract	- 10,000 DKK / per failed delivery within quality limits - 4 times of failed delivery → termination of the contract	- 20,000 DKK on 1 <sup>st</sup> failure in delivery within quality limits - 2 times of failed delivery → termination of the contract	- 15,000 DKK on 1 <sup>st</sup> failure in delivery within quality limits - 25,000 DKK on 1 <sup>st</sup> failure in delivery within quality limits - 3 times of failed delivery → termination of the contract	- 10,000 DKK / per failed delivery within quality limits - 4 times of failed delivery → termination of the contract (Average value of life-time reduction of components etc. + administration + mobile power plants)
18)	Other				Reference signal: DSO will continuously (every 30. sec.) send a reference signal to the Aggregator during every event.	

Table 10: Summary of examples on Flexibility products for load management.

## 5.5.2 FLEXIBILITY PRODUCTS FOR VOLTAGE MANAGEMENT - SUMMARY

1)	Service name	"VoltageSupport"	"VArSupport"
2)	Contract valid from	1 January 2015	1 November 2014
3)	Contract valid until	31 December 2015	31 January 2015
4)	Est. no. of activations during period	100	50
5)	Size of service in power (kW)	N/A	N/A
6)	Size of service in energy (kWh)	N/A	N/A
7)	Max. duration of service per activation (h)	Until critical situation has ended (est. max. 2 hours)	Until critical situation has ended (est. max. 2 hours)
8)	On - Trigger	Signal from the DSO	Signal from the DSO
9)	Off - Trigger	Est. 2 hours from "on"-signal, or by earlier signal from the DSO	Est. 2 hours from "on"-signal, or by earlier signal from the DSO
10)	Geography (specified by unique consumer numbers)	261080-265891	108045-189125
11)	Maximum allowed activation time	5 min.	5 min.
13)	Quality in supply	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 1 min.</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>	<ul style="list-style-type: none"> <li>- <u>Deviation in max. duration:</u> +/- 5 min.</li> <li>- <u>Deviation from, On - Trigger:</u> +/- 5 min.</li> <li>- <u>Acceptable no. of unsuccessful activations:</u> 2</li> </ul>
14)	Pricing (DSO pays Aggregator)	<ul style="list-style-type: none"> <li>- 0 DKK in reservation payment + 500 per activation = estimated to 50,000 DKK for the entire contract period.</li> <li>- In total 50,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>	<ul style="list-style-type: none"> <li>- 10,000 DKK in reservation payment + 500 per activation = estimated to 25,000 DKK for the entire contract period.</li> <li>- In total 35,000 DKK as maximum payment for the entire contract period.</li> <li>- Paid at the end of the period, due to risk of alternative Aggregator ignorance of the contract</li> </ul>

1)	Service name	"VoltageSupport"	"VArSupport"
15)	Estimated price per activation	- 500 DKK	- 500 DKK
16)	Risk issues	Failure in supply, due to: - Faulted communications or control systems between Aggregator and DERs - Faulted communications between Aggregator and DSO - Faulted communication of trigger signal between Aggregator and DSO	Failure in supply, due to: - Faulted communications or control systems between Aggregator and DERs - Faulted communications between Aggregator and DSO - Faulted communication of trigger signal between Aggregator and DSO
17)	Penalty if failed supply	- 15,000 DKK on 1 <sup>st</sup> failure in delivery within quality limits - 25,000 DKK on 2 <sup>nc</sup> failure in delivery within quality limits - 3 times of failed delivery → termination of the contract	- 10,000 DKK on 1 <sup>st</sup> failure in delivery within quality limits - 15,000 DKK on 2 <sup>nc</sup> failure in delivery within quality limits - 3 times of failed delivery → termination of the contract
18)	Other	DSO will continuously (every 30 sec.) send a reference signal to the Aggregator during every event.	

Table 11: Summary of examples on Flexibility products for voltage management.

## 6 BASIC MARKET DESIGN

The conceptual design of Flexibility market place is the subject of this chapter.

### 6.1 MARKET DESIGN

The basic thoughts of a Flexibility market place and the corresponding stakeholders are illustrated in Figure 33. The existing market setup with the energy chain: BRP, Retailer and consumer is unchanged. This is denoted “ordinary electricity” in Figure 33. The new flexible DERs of the consumers can be mobilized by Aggregators. As illustrated in the left hand side of Figure 33, the Aggregators can use this flexibility to provide services to the DSO and TSO. The service to the TSO would be based on the existing ancillary services requested by the TSO, whereas services to the DSO would constitute a new market place.

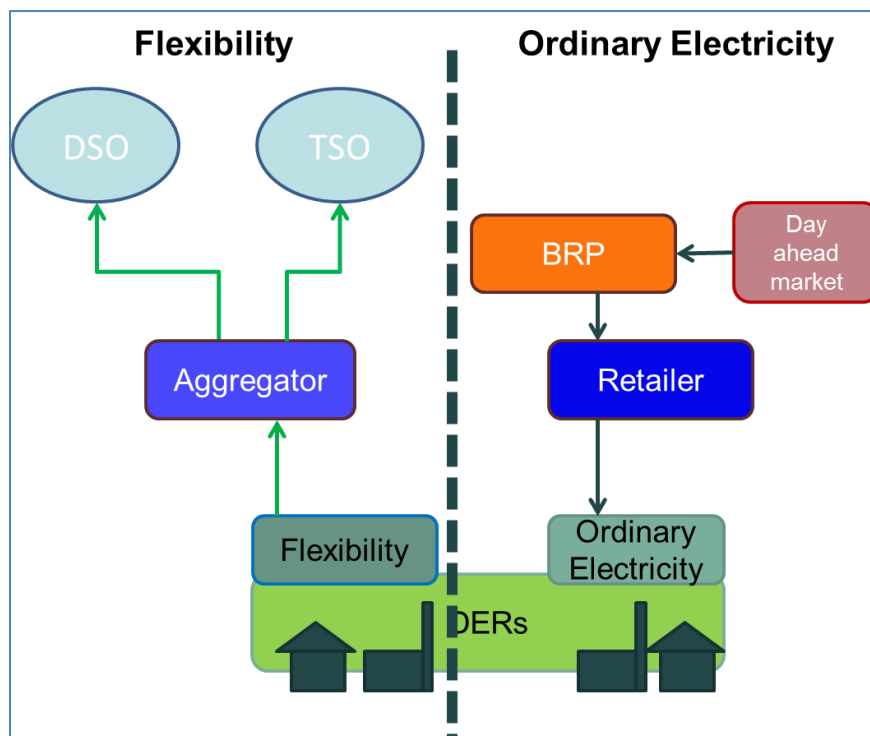


Figure 33: Market setup for trading flexibility products – The bilateral Setup.

As shown in the Figure 33, the flexible DERs of the consumers can be mobilized by Aggregators for providing flexibility products to the DSOs or TSO. This market setup is not completely possible within the current market regulations. The Aggregator may mobilize the flexibility, but the Aggregator would have to be associated with a BRP in order to access to the TSO ancillary markets. However, Aggregators and DSOs can do bilateral business within the current market regulations. In the rest of this report, we will allow the Aggregators and TSO to do business on flexibility without involvement of the BRPs.



Meanwhile, the BRPs access to the TSO ancillary markets is unchanged. Hence the Aggregator can do business directly with the TSO or via the BRP.

In regard of flexibility products for the DSOs, it is expected that the DSOs from his knowledge on grid loading etc. will define what kind of products he will be interested in buying, under what conditions, and where in the grid, see section 5 on product specifications.

Similarly the TSO posts his need for ancillary services - TSO-product – which he is already doing today through the reserve- and regulating power markets. If the Aggregator can fulfill the required properties to attend in the reserve- and regulating power markets, he will be able to, serve the TSO, as needed by the TSO.

Several issues points at a need for a Flexibility Clearing House. The arguments for this are explained in the following section 6.2.

## 6.2 THE NEED FOR A FLEXIBILITY CLEARING HOUSE – FLECH

With the possible economic advantages, for the DSOs and the TSO, in using flexibility as a new alternative the volume in traded flexibility is expected to increase over time.

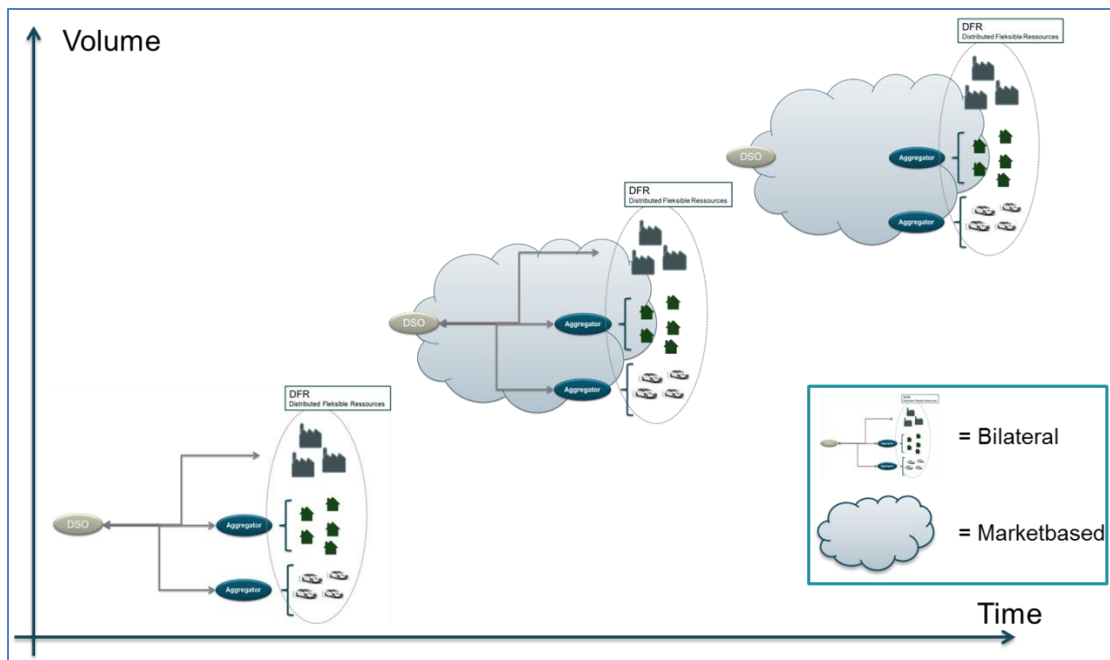


Figure 34: Incremental development of DSO capabilities and market potentials.

In regard of serving the TSO it is expected to follow the present market rules on the ancillary services markets, where the TSO is only interested in having contractual relations to commercial parties (at present only BRPs but Aggregators are expected to be included as outlined in section 6.1).

In regard of serving the DSOs, the DSOs might be willing to engage in a low manageable number of bilateral flexibility contracts. However as the volume in traded flexibility increases, and each DSO requests hundreds of flexibility contracts, the DSO will have a clear incentive to move from making tailor-made contracts for each case, towards a more standardized trading of flexibility.

From this the basic evolution points towards a Clearing House where flexibility can be traded based on standardized contracts. The expected evolution is illustrated in the figure above. This evolution and several other market issues, which is discussed in section 6.2.1 to 6.2.2, point at the need for the flexibility clearing house showed in Figure 35.

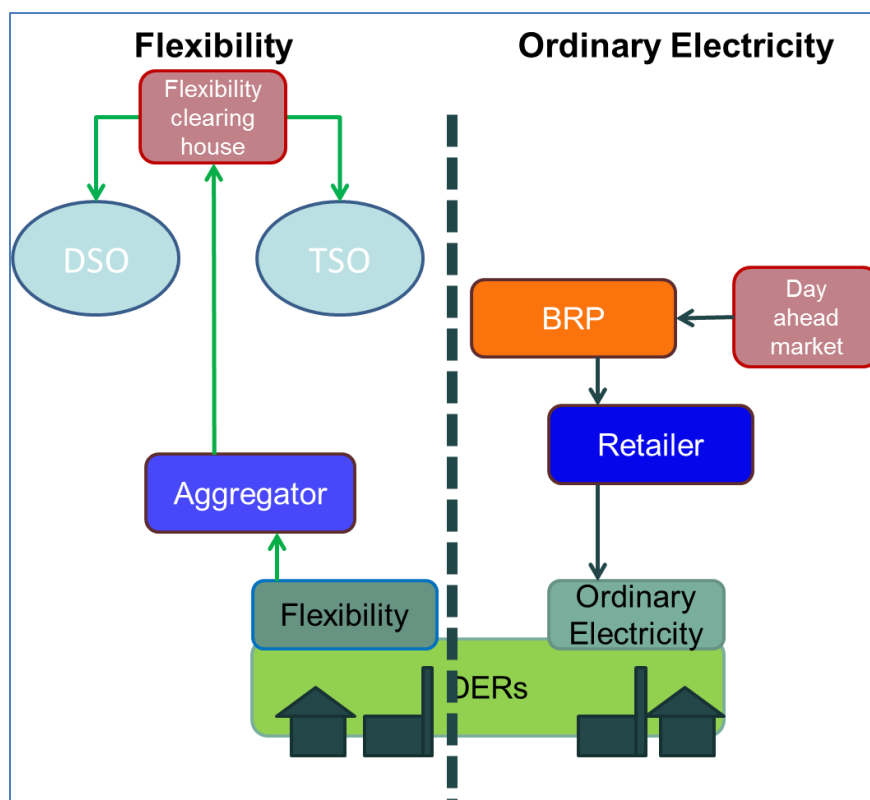


Figure 35: Setup for trading flexibility products – The flexibility-market setup.

Compared to Figure 33, there is only a small change in Figure 35, namely the inclusion of the flexibility clearing house. In the following sections further issues pointing at the need for a flexibility clearing house are discussed.

### 6.2.1 COORDINATION IN SERVING FLEXIBILITY TO BOTH DSO AND TSO

As flexibility can be served from the Aggregator, to both the DSOs and the TSO, there exists a possibility for conflicting demands on flexibility, which needs the coordination: A flexibility demand by the TSO may result in congestions or other burdens e.g. voltage issues to the DSO, and vice versa.

#### EXAMPLE:

An unchangeable condition is that the DSO is obliged to fulfill its basic task of guaranteeing security of supply in their grid. In case the TSO - on the ancillary service markets – from an Aggregator, purchases a down regulation (increased load) from DERs, located in the distribution grid, this may result in overload of the distribution grid and hence cause problems for the DSO. This technical relationship poses a barrier for the DER and the Aggregator to serve the TSO. However, luckily the TSO can normally be served from resources at any place within their system area (globally), whereas the DSO only has few local areas that would risk being affected by the Aggregator and DERs serving the TSO. Therefore the TSO should technically be able to get the needed service without affecting the DSO. This is very roughly illustrated in Figure 36 where the red marking represent local grid areas that cannot take any further load and therefore cannot be included in serving the requested TSO-service, at this specific situation. Said simply: The TSO is excluded from increasing loads by buying flexibility services, in the red marked areas. However plenty of consumers in other areas can still serve the TSO.

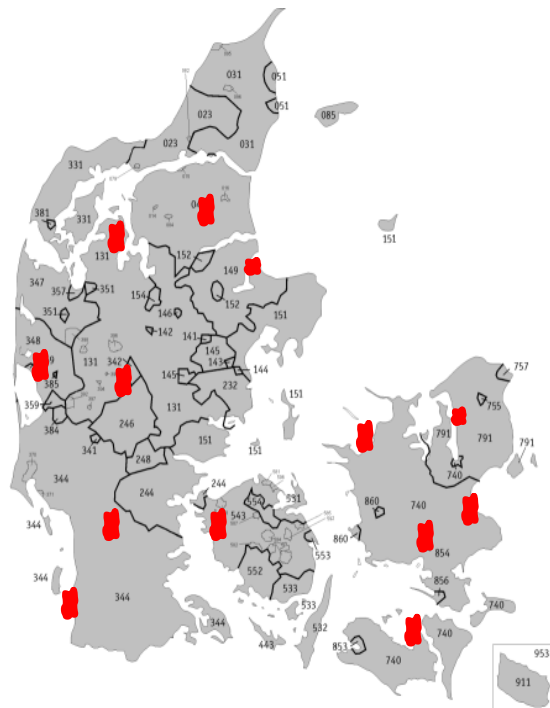


Figure 36: Illustration of the prioritization issue in coordinating conflicting needs for TSO and DSO-services.

Technically coordination should be possible and solutions on this has been given in the article from iPower WP3.7, stating the following list of priority, to the DERs / Aggregator, in case of conflicts in serving flexibility [6].

1. Emergency actions (TSO)
2. Alert actions (TSO/DSO)
3. Local voltage control (DSO)
4. Peak-shaving (DSO)
5. Voltage support (TSO)
6. Mvar bands (DSO)
7. Frequency control (TSO)
8. Other ancillary services (TSO)
9. Imbalance issues (BRP)
10. Power quality (DSO)

Looking at the economical side, market-rules should be clear on how to handle these cases. In Figure 37 below an illustration is made on to local bid being blocked in serving a TSO service, in order to avoid posing problems to the DSO. Hereby the TSO are forced to take the 2<sup>nd</sup> cheapest bids. Perhaps the DSO should pay for this discomfort of the TSO. This underlines that economic rules on this are necessary and it is evident that such kind of rules somehow have to be enforced. The Flexibility Clearing House, could be the place where the enforcement are made.

	Hour of day	Volume [kW]	Direction of service	Location			Price [DKK/kW]	BRP	Aggregator	Supply possibility?
				TSO Area	150/60 kV station	10 kV Feeder				
Bid 4	17:00 - 18:00	800	Upward reg.	DK2	HVE	3564	1,5	DONG Energy	Betterplace	
Bid 17	17:00 - 18:00	400	Upward reg.	DK2	HVE	44353	1,5	DONG Energy	Betterplace	
Bid 16	17:00 - 18:00	700	Upward reg.	DK2	HVE	4456	1,6	DONG Energy	EFlexPartner	
Bid 6	17:00 - 18:00	500	Upward reg.	DK2	HVE	3452	1,7	DONG Energy	Betterplace	
Bid 14	17:00 - 18:00	600	Upward reg.	DK2	HVE	3656	1,7	DONG Energy	Betterplace	Blocked
Bid 7	17:00 - 18:00	800	Upward reg.	DK2	HVE	6756	1,8	DONG Energy	Betterplace	
Bid 15	17:00 - 18:00	1000	Upward reg.	DK2	HVE	456	1,8	DONG Energy	EFlexPartner	
Bid 19	17:00 - 18:00	1200	Upward reg.	DK2	HVE	4654	1,9	DONG Energy	EFlexPartner	
Bid 18	17:00 - 18:00	800	Upward reg.	DK2	HVE	7856	1,9	DONG Energy	EFlexPartner	
Bid 2	17:00 - 18:00	900	Upward reg.	DK2	HVE	3456	2	DONG Energy	Betterplace	
Bid 8	17:00 - 18:00	700	Upward reg.	DK2	HVE	8578	2,1	DONG Energy	Betterplace	
Bid 13	17:00 - 18:00	700	Upward reg.	DK2	HVE	6465	2,1	DONG Energy	Betterplace	
Bid 9	17:00 - 18:00	500	Upward reg.	DK2	HVE	7686	2,2	DONG Energy	Betterplace	Blocked
Bid 10	17:00 - 18:00	900	Upward reg.	DK2	HVE	3474	2,2	DONG Energy	Betterplace	
Bid 3	17:00 - 18:00	600	Upward reg.	DK2	HVE	5257	2,4	DONG Energy	Betterplace	
Bid 12	17:00 - 18:00	700	Upward reg.	DK2	HVE	9876	2,4	DONG Energy	EFlexPartner	
Bid 20	17:00 - 18:00	800	Upward reg.	DK2	HVE	5834	2,5	DONG Energy	EFlexPartner	
Bid 11	17:00 - 18:00	600	Upward reg.	DK2	HVE	35636	2,6	DONG Energy	EFlexPartner	
Bid 5	17:00 - 18:00	400	Upward reg.	DK2	HVE	36578	2,7	DONG Energy	EFlexPartner	
Bid 1	17:00 - 18:00	600	Upward reg.	DK2	HVE	34563	3	DONG Energy	EFlexPartner	

Figure 37. Illustration of the financial setup in coordinating conflicting needs for TSO and DSO-services.

---

### 6.2.2 RISK OF MALICIOUS BEHAVIOUR FROM THE AGGREGATOR

Another issue that points toward a need for a Flexibility Clearing House is the fact that the Aggregators, without any market-rules, are able to produce conflicts that he afterward can be paid to solve. This can obviously not be allowed.

#### EXAMPLE 1:

If the Aggregator are vending a down-ward regulation to the TSO (leading to increased load in the distribution grid). From this the Aggregator could subsequently be asked for a down regulation (with other customers) to assist the DSO. Neither the DSO nor the TSO will basically know that this is happening. The Aggregator can therefore do this unseen.

#### EXAMPLE 2:

An Aggregator who has a contract with a sufficient amount of consumers on one feeder may exploit his ability to control DER assets and cause overloads in the distribution grid that may impose the DSO to engage in a load reduction contracts with him. This is a mechanism that allows the Aggregators to create a problem that the DSO is paying the Aggregator to solve himself. Nevertheless, the Aggregator hereby, in the long run, undermines his business by doing so (as the DSO will automatically seek for other solutions). These trading schemes are of course unwanted in a market.

The solution to handling these unwanted incentives to the Aggregators, could be a Flexibility Clearing House to control and regulate all commercial contracts. One simple rule could be that the Aggregator can only use the DERs to serve one party (the DSO or the TSO) at a time. The DERs could so-to-say be “flagged” while they are activated, and as long as the DERs are “flagged” they cannot be used for other services.

### 6.3 POSSIBLE TRADING SETUPS

As mentioned in the beginning of section 6.2, by increased volume in trading flexibility, a demand on standardized contracts are expected to arise at the DSOs (probably also at Aggregators). This points toward regular trading setups, at a Flexibility Clearing House, as is similarly known from e.g. e-bay.

However looking at more specific setups in trading flexibility products, three possible trading setups are identified and called: 1. Bilateral contracts. 2. Auctions. 3. Supermarket.

1. Bilateral contracts:

DSO-products in terms of volume and price are negotiated between the DSO and Aggregators through individual bilateral contracts. However, as the DSO is the only party who knows where the need for DSO-products are, the DSO's are expected to be the ones specifying the DSO-products needed and presenting these to the Aggregators they are negotiating with. E.g. the DSO has the initiative. On the basis of this Aggregators enter negotiations with the DSOs. This kind of trading setup is expected to be the most common in the beginning of trading flexibility. Furthermore a real market on flexibility products are not expected to be established before flexibility are traded in sufficiently large volumes. Bilateral contracts are therefore expected to be made before the Flexibility Clearing House is established. Making bilateral contracts, however, implies large work on negotiating the wanted properties by the DSO.

2. Auctions:

With increased volume in traded flexibility and the expected following establishment of a Flexibility Clearing House, an auction based trade setup are expected to arise. Again the DSO has the initiative as being the only party who knows where the need for DSO-products is. The DSO proposes the volume and price request in terms of a standardized DSO-product, through the Flexibility Clearing House. The Standardized DSO-products will ensure that all properties are specified beforehand and therefore costs in negotiations will be spared. Further; the Aggregators will be able to see the DSOs demands shortly after at the Flexibility Clearing House – webpage. On the basis of this the Aggregators submit bids for satisfying the requested DSO-product of DSO, in terms of price and volume. The DSO chooses from the provided bids from the Aggregators, and standardized contract are automatically made according to the market-rules of the Flexibility Clearing House.

3. Supermarket:

In opposition to the auction based setup, in this setup the Aggregators have the initiative. The Aggregators will from knowledge on the historically bought DSO-products, be able to estimate where the DSO might be interested in buying a DSO-product. From this knowledge Aggregators could stipulate standardized products of various volumes and prices specified. Like in the “supermarket”, the customer of flexibility, in this case the DSO's and the TSO, will select the product needed, based on the proposed offers from the Aggregators.

These trading setups do not necessarily replace each other, and will most likely run in parallel at a certain period of time in the future, see Figure 34. However, it is expected that the objective of reducing costs in delivering flexibility products will inflict a transition towards the auction and supermarket based setups.

## 7 MARKET ISSUES / PROBLEMS

Although several possibilities in mobilizing flexibility are given above, there are still a number of market issues which needs to be solved. Finding solutions to these issues are crucial. Five issues have been identified and will be described in detail in section 7.1 to 7.5, below.

### 7.1 IMBALANCE WHEN SERVING FLEXIBILITY – PLACEMENT OF IMBALANCE COSTS

Each time the Aggregator, with his affiliated DERs, serves a flexibility product to either the DSO or the TSO directly, he will cause an imbalance to the Balance responsible party (BRP) in the BRP electricity supply in the ordinary electricity market. As the market rules are today, the BRP faces a cost to cover the imbalance each time his imbalance is against the system needs.

As the BRP has no influence on the served flexibility, as suggested in Figure 35, this effect doesn't seem fair.

What other solutions could be feasible then? In Figure 38 to Figure 41 four different solutions are illustrated, whereas the first one is the basic case according to today's rules, where the BRP is to cover the imbalance costs. Looking at alternatives the following possibilities in placement of the imbalance cost are illustrated:

1. At the Aggregator (Figure 39).
2. At the demander – DSO and TSO (Figure 40).
3. At the Flexibility Clearing House – representing a joint solidary covering of imbalance cost, divided on participants in the flexibility market, with a common average price (Figure 41).

At the Flexibility Clearing House: Starting with the last possibility. Placing the imbalance cost at the Flexibility Clearing House will lead to largely increased administration at FLECH. Furthermore it will lead to the fact that no-one will care about imbalances, which is not necessarily bad, however, it will probably lead to higher general (societal) imbalances, if no-one the real effect is hidden behind a leveling scheme as suggested here.

At the demander (DSO and TSO): The second possibility that the demander (DSO and TSO) should pay the associated imbalance costs at each activation. This seems fair as e.g. the DSO's demand for help are leading to the imbalance, making a total price of:

$$\text{Price}_{\text{total}} = \text{Price on flex} + \text{Associated imbalance costs}$$

However the DSO has little experience and knowledge of imbalance costs.

In case of the TSO, this is more or less solved. When a provider of regulating power is activated by the TSO, the provider will issue an updated production schedule to the TSO and the provider is then accounted according to the new schedule. In this way imbalances in the energy markets are omitted.

At the Aggregator: This solution seems fair, as it is the Aggregator's control of the DER, that leads to the imbalance. From this the Aggregator must reimburse the imbalance costs to the involved BRPs, each time the Aggregator activates a flexibility product. As both the Aggregator and the BRPs are able to know the size of imbalance the aggregator causes, a rather precise

reimbursement is possible to be made. It will however lead to higher costs on flexibility products, as the Aggregator needs to have the costs covered, in order to run a healthy business. The Aggregator can only get it covered from forwarding them to the DSO or TSO. However the Aggregator can do this in various ways, just making sure that he somehow gets them covered by the prices he is bidding to the DSO and TSO. Therefore Figure 39 is suggested as the solution to the imbalance cost placement issue.

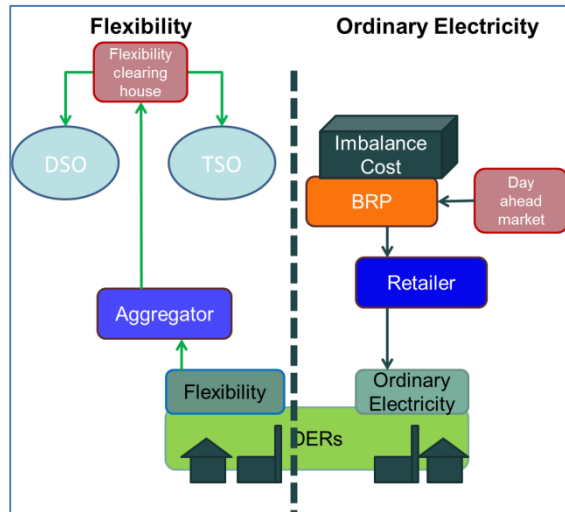


Figure 38. Illustration of imbalance costs carried by the BRP.

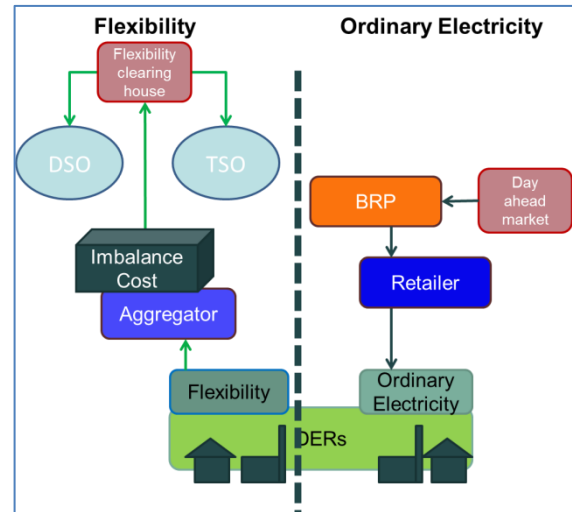


Figure 39. Illustration of imbalance costs carried by the Aggregator.

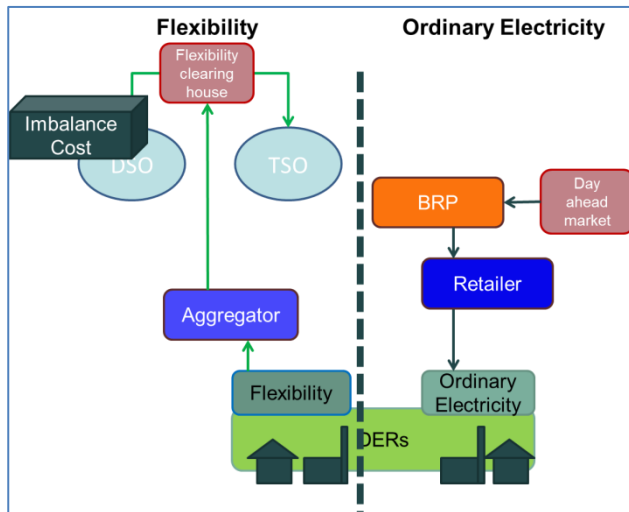


Figure 40. Illustration of imbalance costs carried by the demander, i.e. DSO or TSO.

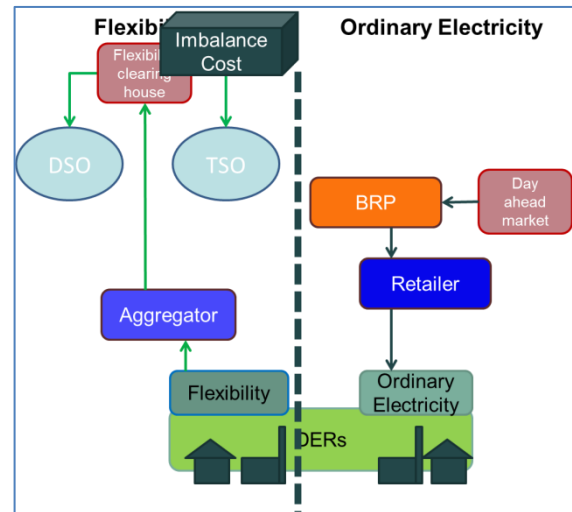


Figure 41. Illustration of imbalance costs carried by the Flexibility Clearing House (joint solidary covering of imbalance cost).



## 7.2 AGGREGATOR AND RETAILER CONFLICT - CUSTOMER RIGHTS?

In section 3 we assume that the Aggregators and the Retailers are two different commercial companies. In the future we could assume that all customers are billed on basis of hourly readings and the Retailer closes contracts with consumers on basis of an energy price that more or less reflects the spot market price.

In parallel, we could assume that an Aggregator closes contract with the group of consumers who have a flexibility potential in terms of cooling, electrical vehicles, heat pumps etc. The business model facing the consumers would be to potentially interrupt their consumption against payment.

Faults in the grid or occasional overload situation may result in the DSO purchasing load reduction from the Aggregator at a time where prices are low, which results in the customers being forced to consume energy in the peak price hours (or in the low price hours). Anyhow it cannot be expected that ordinary household consumers will be able to see through the complex and the concept may be argued by the Danish Customer Authorities.

However corresponding complexities in products also exists in various other consumer products such as insurance, banking, telecom, etc. The solutions from those are regulations that makes the products as transparent as possible. As long as the business players comply to these set of regulations the consumers should be protected from unforeseen costs.

## 7.3 BANKRUPTCY OF AGGREGATORS

Contracting of e.g. "PowerCut planned" is meaningful to the DSO in order to postpone required grid reinforcement investments. The product requires a long term contract and that the load reduction is enforced every single day as load profiles are more or less the same every day (in the same part of the year).

In this case the DSO has actually postponed required grid reinforcement investment due to the purchased flexibility contract. In case of a bankruptcy of the Aggregator holding the contract, the flexibility-service will vanish from one day to the next and risk resulting in local blackouts until other means are found.

In regard of searching a new flexibility contract with another Aggregator (until reinforcements are made) the DSO's negotiation position is very difficult as failure to close a new contract on short terms means continued risk of local blackouts. This may be reflected in high payment claims from a new Aggregator

One solution could be to authorize the DSO to take over the bankrupt Aggregators affiliated flexible consumers with the purpose to maintain the daily load reduction in a period that allows the DSO an actual choice between grid reinforcement work or a new flexibility contract. The solution requires a Clearing House to observe that the contractual agreements with regular consumers are respected. A disadvantage in this solution is that it do not comprise with the unbundling legislation as the rules of unbundling prevents monopolies (DSOs) from being operators of "production", as could likely be the case here.

Another solution could be to authorize the flexibility clearing house (FLECH) to take over the bankrupt Aggregators responsibilities. The advantage in this is that the clearing house is as a neutral player. It would correspond to the governmental stability company taking over obligations of bankrupt banks, until the activities can be sold off to other existing banks. This will likely not violate any legislation; however it will put an administrative burden on the FLECH that should probably be covered solidarically by the users of FLECH.

Thirdly the use of mobile powerplants could be an acceptable solution to the DSO, until other means are found.

## 7.4 INCENTIVES FOR DSO TO INVEST IN FLEXIBILITY SERVICES

At present the situation in Denmark are rather critical in regard to ensure the socio-economically optimal smart grid investments at the DSO.

- a) Today the fact is that the DSOs are benchmarked against each other on overall costs. The idea is to create some kind of competition between the DSOs in being cost-effective. There is a mathematical model quantifying this benchmarking, evaluating costs per grid volume, at each DSO:  $\frac{\text{Total costs [DKK]}}{\text{Grid volume [km and pieces]}}$

This Benchmarking model holds one of the issues in this context. Investments in equipment needed for the DSO to exploit the possibilities in smart grid, that are cheaper than conventional grid upgrades, cannot be valued as real investments – which thereby represents a higher grid volume. Because of this the result is that smart grid investments will make the index or fraction above larger, which draws the DSO in the wrong direction – benchmarking wise. Eventually, it will lead to higher yearly economic punishment of the DSO choosing smart grid investments. Hence, the Benchmarking model should be changed in order to align smart grid investments, with regular investments.

- b) Furthermore, where investments in conventional grid upgrades are evaluated as needed investments, the DSO will be able to have a rate of return from the investment (ROI) according to the long interest + 1%, which at present is approx. 5%. This is crucial to ensure the necessary grid investments. However the DSO will not be able to benefit on smart grid investments, which equally solves the issues, that leads to necessary grid investments. This will imply that smart grid investments will not be chosen, although in some cases it might be cheapest and an equally good solution.

## 7.5 ADJUSTMENTS IN TSO ANCILLARY SERVICE MARKETS

At present there are several barriers on Aggregators, supplying flexibility from aggregated DERs to the TSOs ancillary service markets. These barriers have to be removed in order to unlock the full value of mobilizing flexibility from DERs. The most critical barriers for having Aggregators supplying the TSOs ancillary service markets are:

1. The requirement that you have to be a BRP, to be a supplier within the TSOs ancillary service markets.
2. Minimum bid size within the regulating power market (RPM) is at present 10 MW.
3. There is at present a strict requirement on real-time measurement from resources delivering to the RPM.
4. At several ancillary service markets only symmetrical bids (bids where both upward- and downward regulation are served) are accepted.

The listed barriers are requirements, which are designed and very adequate for conventional power plants. However, these and several other barriers could be removed in order to open up for the mobilization of flexibility from small scale units.

## 8 RECOMMENDATION OF IPOWER DEMONSTRATIONS

On the basis of the descriptions in the sections above, the workgroup behind this report recommend that the following trading of DSO-products is demonstrated within the iPower project:

- 1) DEMO RECOMMENDATION 1: – Market based activation of “PowerCut – Planned”
- 2) DEMO RECOMMENDATION 2: – Market based activation of “PowerMax”
- 3) DEMO RECOMMENDATION 3: – Market based activation of “PowerCap”
- 4) DEMO RECOMMENDATION 4: – (PERSPECTIVATION) – Market based activation of “VArSupport”
- 5) DEMO RECOMMENDATION 5: – (PERSPECTIVATION) – Market based coordination between DSO and TSO on compensating the TSO to choose 2<sup>nd</sup> cheapest bid

However, before substantial resources are used on live demonstrations each demonstration case should be pretested through role-playing, posing participants with the described incentives of each market-player. This role-playing session could form an important task in order to identify the critical details. Finding those details at the live demonstrations would risk coursing a substantial use of resources.

All of the recommended demonstrations should, as a minimum, contain the steps illustrated in Figure 42. Important results from these demonstrations, which should be recorded, are:

- Time spent per step
- Seamless interface between [DSO]-[Flexibility clearing house] and [Flexibility clearing house]-[Aggregator]
- Verification of delivery. Quality and possible minimization of time spent
- Quality within delivery according to specifications on geography (delivery from certain consumer numbers)
- Virtual payment

According to [7], and the demonstration plan described herein, the demonstrations are fitting perfect into demonstration point 6 and 7, in the inserted list below.

### Round 1

1. Flexibility Interface. Demonstrate that the information model enables DER to participate in flexibility market
2. Portfolio Aggregation on Elspot. Optimize load flow in respect to the day ahead energy market.
3. TSO: Manual regulating power and Tertiary reserve market participation
4. TSO: Optimization across Elspot and Man. Reg./Tertiary reserve market
5. DSO: Monitoring of the load on the distribution grids (0,4 – 10 kV)– In Real-time and at low cost
6. DSO: Congestion management control (WP3.4) - bilateral
7. TSO-DSO Cross Market Participation (WP3.7)

The demonstrations are expected to be carried out within the tasks of WP3.4 and WP4. In this context it is expected that the actual planning of demonstrations will be done in these tasks, on the basis of the descriptions within this report, especially Table 10.

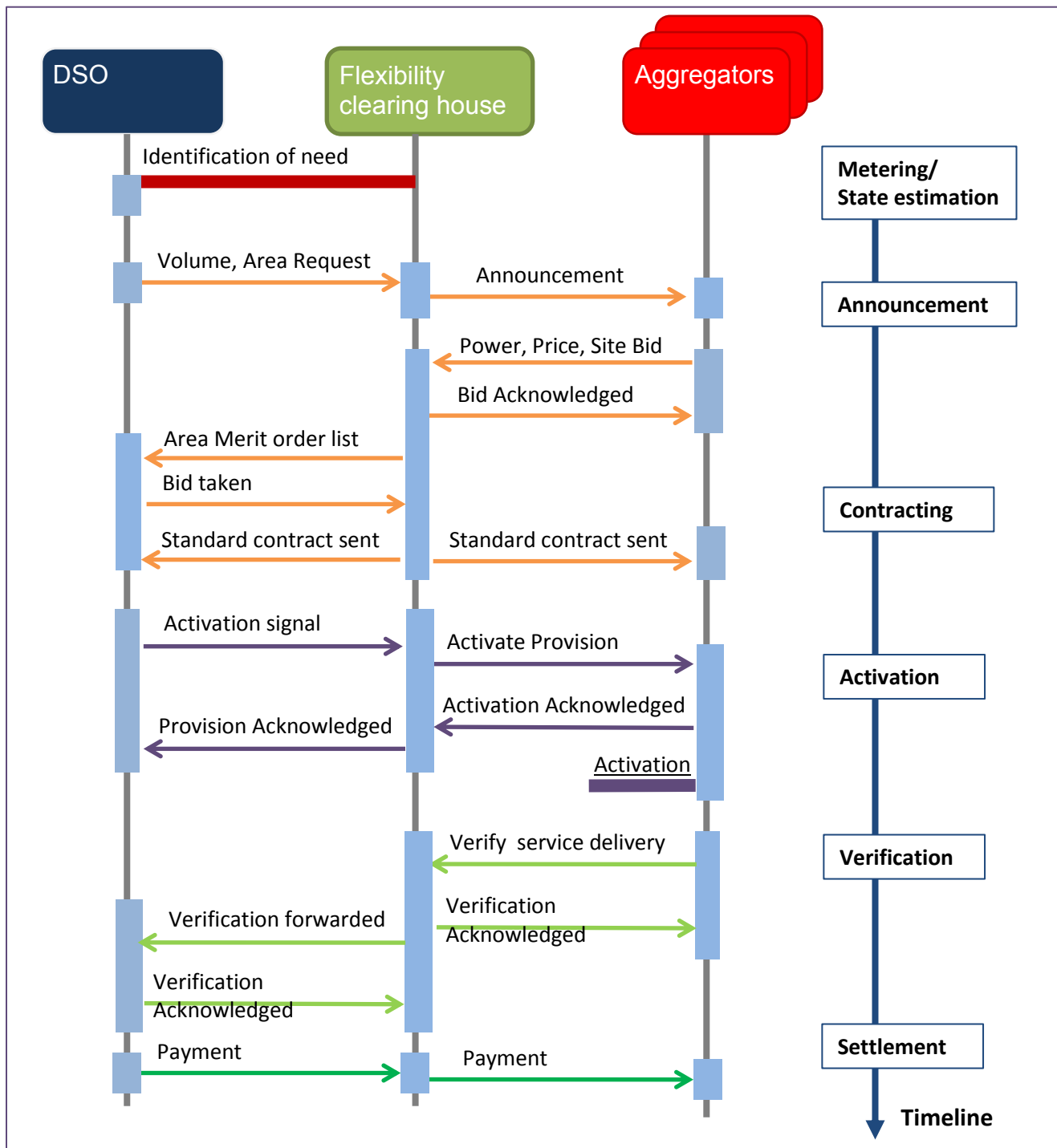


Figure 42: Sequence diagram

## 9 CONCLUSION

Increased consumer DER flexibility can be beneficial to society, both in terms of utilizing our electricity infrastructure to an even higher extend and to secure balance between power consumption and production in each and every second.

This report has been focused on putting substance into these visions. This has been done by focusing on what types of flexibility products that could be of interest to distribution system operators (DSOs), in order to make them utilize their electricity grid infrastructure to an even higher extend. It has been done on the basis of real cases the DSOs either experience today or are expecting that they could face in the future.

All of the DSO-products have been described in high detail, and recommendations on which parameters to include when contracting the products at Aggregators have been given.

Furthermore the economic incentives for the DSOs in buying flexibility products have been sketched, showing that cost-specifications from the DSO hand side, will be based on time-value-of-money in the deferral of costs for grid upgrades, and in addition to this minimization of costs for immediate depreciation of Assets.

On the basis of this, recommendations on a feasible market setup, for trading DSO-products have been given, focusing on making it as simple and inexpensive as possible.

In addition, as for every new development lots of critical details appear. In this report a substantial number of these critical details in regard to trading flexibility have been discussed and recommendations for solutions have been given.

Finally, recommendations on how to demonstrate DSO-products within the iPower project are given in order find other critical details that still are remaining unforeseen.

As a final conclusion, the demand from DSOs in buying flexibility products is expected to grow. Demonstrating the feasibility in using DSO-products will contribute to the removal of business-uncertainty to the DSOs.

## 10 REFERENCES

- [1] J. B. M. P. a. J. S. Klaus Trangbæk, »Exact Power Constraints in Smart Grid Control,« Proceedings of the 50th IEE Conference on Decission and Control and European Control Conference, Orlando, 2011.
- [2] D. E. A. David Victor Tackie, D.-C. Philip James Douglas, D. E. Hans-Henrik Holm-Hansen, D.-C. Henrik W. Bindner, L. U. Olof Samuelson og B. Helena Segerberg, »iPower WP3.1-report: Ensuring Sufficient capacity using Smart Grid solutions,« iPower, Copenhagen, 2012.
- [3] Energinet.dk, »Teknisk Forskrift : TF 2.1.3 Dansk MVar-ordning,« Energinet.dk, 2010.
- [4] E. P. Engineering, »SYNCHRONOUS GENERATORS,« [Online]. Available: <http://www.eguprg.cz/synchronous-generators>. [Senest hentet eller vist den 03 2013].
- [5] T. Ackermann og et al., Wind Power in Power Systems, ISBN: 0-470-85508-8.
- [6] H. Jóhannsson, H. Hansen, L. H. Hansen, H.-H. Holm-Hansen, P. D. Cajar, H. Bindner og O. Samuelsson, »Coordination of System needs and provision of Services,« i *CIREN 2013, International Electricity Conference & Exhibition*, Stockholm, 2013.
- [7] J. Østergaard, L. H. Hansen og et al., »White paper regarding iPower Coordination Strategy,« iPower, 2012.